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(54) **ORGANIC LIGHT EMITTING DIODE
HAVING LOW DRIVING VOLTAGE, HIGH
BRIGHTNESS, AND EXCELLENT LIGHT
EMITTING EFFICIENCIES**

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See application file for complete search history.

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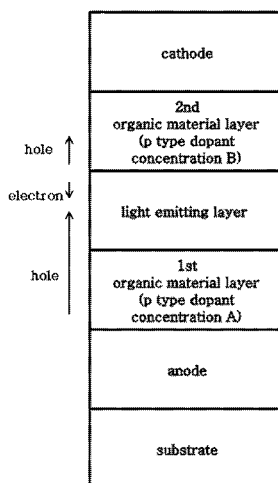
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ABSTRACT

An organic electroluminescent device includes an anode, a cathode, a light emitting layer provided between the anode and the cathode, a first organic material layer being in physical contact with the anode and doped with a p-type dopant, and a second organic material layer being in physical contact with the cathode and doped with a p-type dopant. The concentration of the p-type dopant in the first organic material layer is 50% by weight or more and less than 100% by weight.

20 Claims, 4 Drawing Sheets



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Figure 1

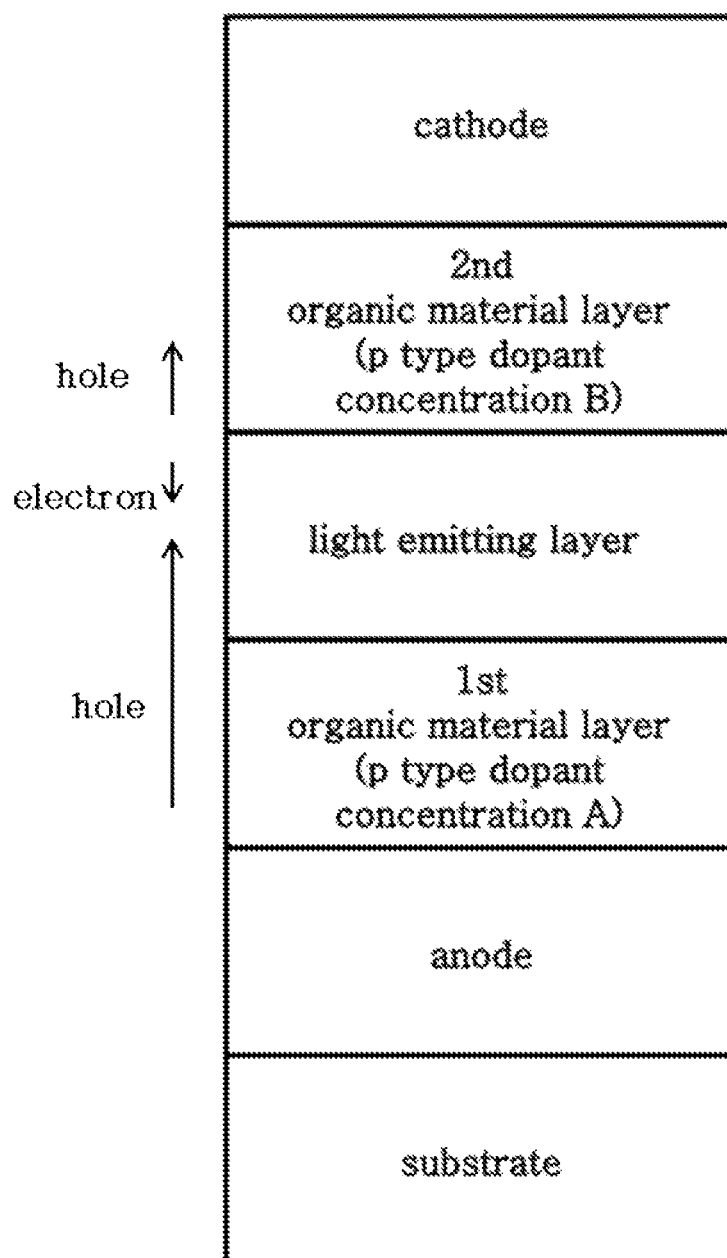


Figure 2

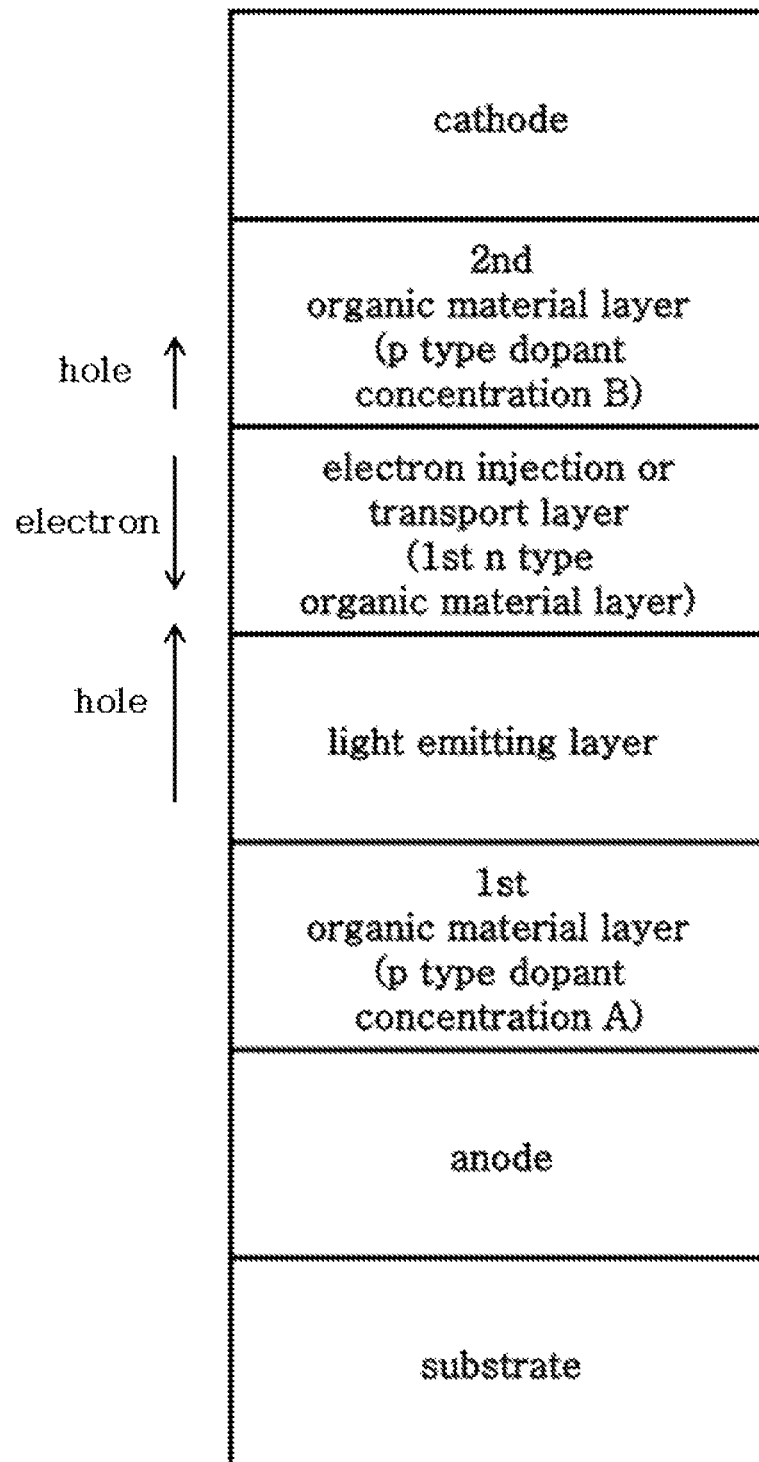


Figure 3

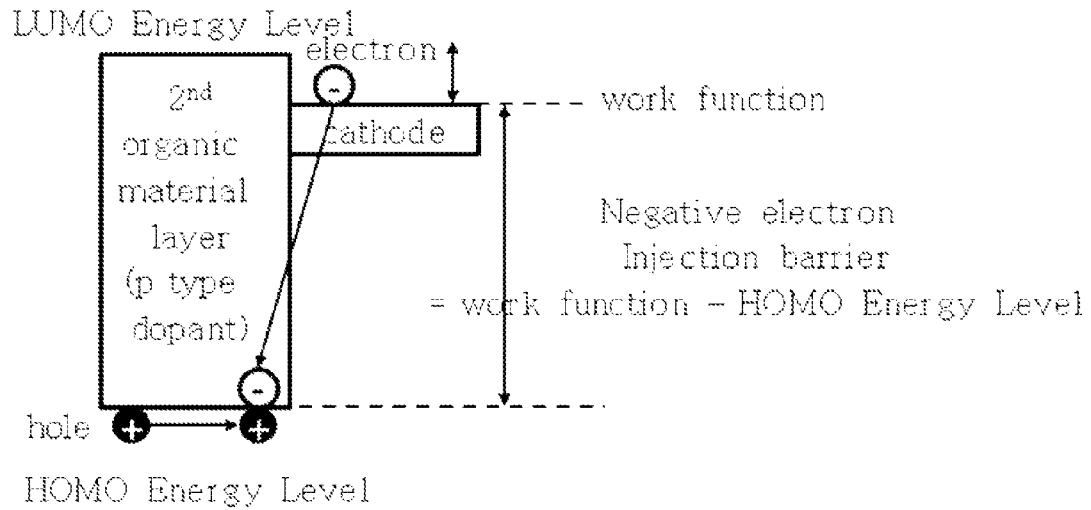


Figure 4

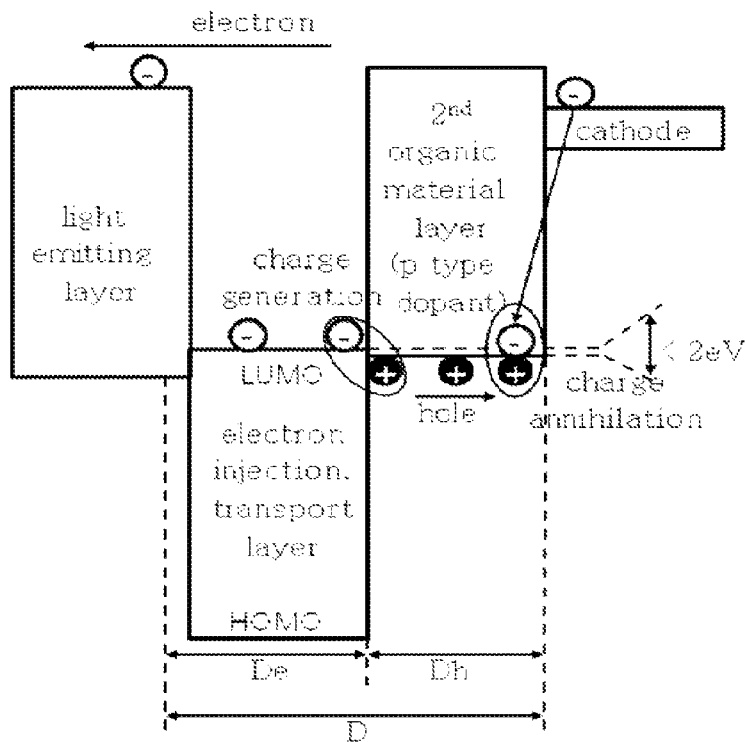
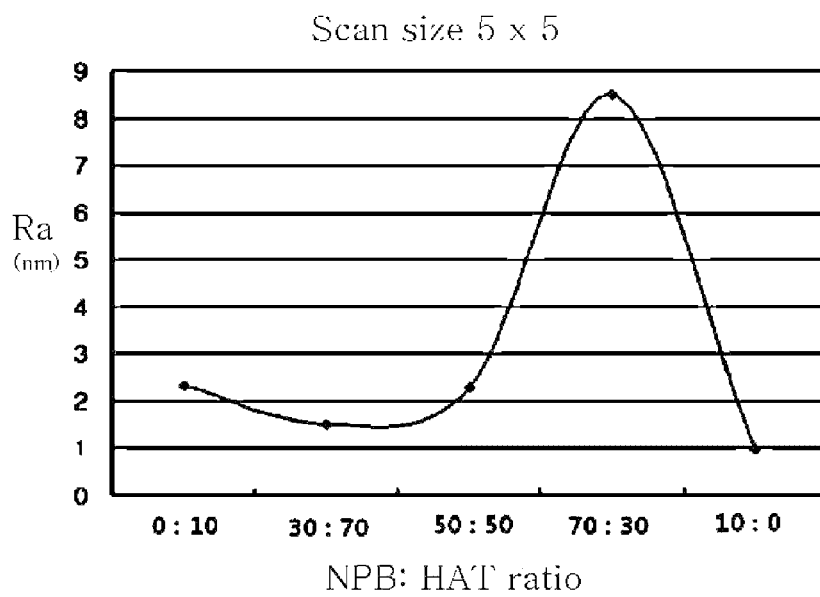


Figure 5



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ORGANIC LIGHT EMITTING DIODE HAVING LOW DRIVING VOLTAGE, HIGH BRIGHTNESS, AND EXCELLENT LIGHT EMITTING EFFICIENCIES

This application is a 35 USC §371 National Stage entry of International Application No. PCT/KR2013/004853, filed on May 31, 2013, and claims priority of Korean Application No. KR 10-2012-0058946, filed May 31, 2012, which are each hereby incorporated by reference in their entirety.

TECHNICAL FIELD

The present description relates to an organic electroluminescent device.

This application claims priority from Korean Patent Application No. 10-2012-0058946, filed on May 31, 2012, at the KIPO, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND ART

An organic electroluminescent device converts a current into visible light by injecting electrons and holes from two electrodes into an organic material layer. The organic electroluminescent device may have a multilayer structure including two or more organic material layers. For example, the organic electroluminescent device may further include an electron or hole injection layer, an electron or hole blocking layer, or an electron or hole transporting layer, if necessary, in addition to a light emitting layer.

Recently, as the use of the organic electroluminescent device has been diversified, studies on materials, which may improve the performance of the organic electroluminescent device, have been actively conducted.

DETAILED DESCRIPTION OF THE INVENTION

Technical Problem

The present specification describes an organic electroluminescent device having a novel structure.

Technical Solution

An organic electroluminescent device according to an exemplary embodiment of the present specification includes: an anode; a cathode; a light emitting layer provided between the anode and the cathode; a first organic material layer associated with the anode and doped with a p-type dopant; and a second organic material layer associated with the cathode and doped with a p-type dopant, in which a content of the p-type dopant of the first organic material layer is 50% by weight or more and less than 100% by weight in the first organic material layer.

According to another exemplary embodiment of the present specification, when a concentration of the p-type dopant in the first organic material layer is A % by weight and a concentration of the p-type dopant in the second organic material layer is B % by weight, $A-B \geq B$ may be satisfied.

According to still another exemplary embodiment of the present specification, when a concentration of the p-type dopant in the first organic material layer is A % by weight and a concentration of the p-type dopant in the second organic material layer is B % by weight, $A-B \geq 1.5 B$ may be satisfied.

According to yet another exemplary embodiment of the present specification, when a concentration of the p-type

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dopant in the first organic material layer is A % by weight and a concentration of the p-type dopant in the second organic material layer is B % by weight, $A-B \geq 2 B$ may be satisfied.

Advantageous Effects

Exemplary embodiments according to the present specification may provide an organic electroluminescent device having low driving voltage, high brightness, and excellent light emitting efficiency by allowing both an organic material layer associated with an anode and an organic material layer associated with a cathode to include a p-type dopant, and setting a concentration of the p-type dopant in the organic material layer associated with the anode to be 50% by weight or more. In particular, when the concentration of the p-type dopant in the organic material layer associated with the anode and the concentration of the p-type dopant in the organic material layer associated with the cathode are controlled within a specific range, it is possible to further improve the aforementioned performance of the device.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 illustrates a stacked structure of an organic material layer of an organic electroluminescent device according to an exemplary embodiment of the present specification.

FIG. 2 illustrates a stacked structure of an organic material layer of an organic electroluminescent device according to another exemplary embodiment of the present specification.

FIG. 3 illustrates a movement of an electric charge between a second organic material layer and a cathode in the organic electroluminescent device illustrated in FIG. 1.

FIG. 4 illustrates a movement of electric charges among an electron injection or transporting layer, a second organic material layer, and a cathode in the organic electroluminescent device illustrated in FIG. 2.

FIG. 5 is a graph showing roughness of an organic film according to the concentration of the p-type dopant.

BEST MODE

Hereinafter, exemplary embodiments exemplified in the present specification will be described in detail.

In the present specification, an n-type means n-type semiconductor characteristics. In other words, an n-type organic material layer is an organic material layer having a characteristic that electrons are injected or transported at the LUMO energy level, and an organic material layer having a characteristic of a material having an electron mobility greater than a hole mobility. Conversely, a p-type means p-type semiconductor characteristics. In other words, a p-type organic material layer is an organic material layer having a characteristic that holes are injected or transported at the highest occupied molecular orbital (HOMO) energy level, and an organic material layer having a characteristic of a material having a hole mobility greater than an electron mobility. "An organic material layer which transports electric charges at the HOMO energy level" and the p-type organic material layer may be used as having the same meaning. Further, "an organic material layer which transports electric charges at the LUMO energy level" and the n-type organic material layer may be used as having the same meaning.

In the present specification, the p-type dopant means an electron-acceptor material.

In the present specification, an energy level means a size of energy. Accordingly, even when an energy level is expressed in a negative (-) direction from a vacuum level, the energy

level is interpreted to mean an absolute value of the corresponding energy value. For example, the HOMO energy level means a distance from the vacuum level to the highest occupied molecular orbital. In addition, the LUMO energy level means a distance from the vacuum level to the lowest unoccupied molecular orbital.

In the present specification, an electric charge means an electron or a hole.

In the present specification, an "organic material layer associated with the anode" means an organic material layer which is disposed closer to an anode than a cathode based on a light emitting layer, and an "organic material layer associated with the cathode" means an organic material layer which is disposed closer to a cathode than an anode based on a light emitting layer. At this time, the organic material layer associated with the anode or cathode may include an organic material layer which is in physical contact with the anode or the cathode. However, in exemplary embodiments described in the present specification, the case where an additional layer is provided between the organic material layer associated with the anode or the cathode and the anode or the cathode is not completely ruled out.

In the present specification, the p-type dopant means a material that relatively receives electrons for a host material in the organic material layer including the p-type dopant. Conversely, a host material in the organic material layer including the p-type dopant means a material that relatively gives electrons for the p-type dopant.

An organic electroluminescent device according to an exemplary embodiment of the present specification includes: an anode; a cathode; a light emitting layer provided between the anode and the cathode; a first organic material layer associated with the anode and doped with a p-type dopant; and a second organic material layer associated with the cathode and doped with a p-type dopant. In other words, the organic electroluminescent device includes the p-type dopant both in the organic material layer associated with the anode and the organic material layer associated with the cathode. As described above, even when the organic material layer is formed to be thick by including an organic material layer in which the p-type dopant is included in a larger amount on both sides, a driving voltage may be maintained at a low level.

In the exemplary embodiment, the content of the p-type dopant of the first organic material layer is 50% by weight or more and less than 100% by weight in the first organic material layer. The selection of the concentration of the p-type dopant in the first organic material layer within the range may exhibit an effect of reducing the driving voltage and is advantageous for stability and electrical characteristics of the device. In particular, in the case where a compound of Formula 1 to be described below is used as the p-type dopant of the first organic material layer, effects of reducing the driving voltage and improving the stability of the device may be maximized when the content of the compound of Formula 1 in the first organic material is 50% by weight or more.

Meanwhile, when the content of the p-type dopant is low in the second organic material layer, roughness occurs by other materials of the second organic material layer, and a light scattering effect may be exhibited, thereby exhibiting a light extraction effect. For example, when the compound of Formula 1 to be described below is used as the p-type dopant of the second organic material layer, and an aryl amine compound, specifically, NPB is used as a material to be doped in the second organic material layer, the concentration of the p-type dopant in the second organic material layer needs to be lower than that in the first organic material layer.

According to another exemplary embodiment of the present specification, when the concentration of the p-type dopant in the first organic material layer is A % by weight and the concentration of the p-type dopant in the second organic material layer is B % by weight, $A-B \geq B$ may be satisfied.

According to still another exemplary embodiment of the present specification, when the concentration of the p-type dopant in the first organic material layer is A % by weight and the concentration of the p-type dopant in the second organic material layer is B % by weight, $A-B \geq 1.5 B$ may be satisfied.

According to yet another exemplary embodiment of the present specification, when the concentration of the p-type dopant in the first organic material layer is A % by weight and the concentration of the p-type dopant in the second organic material layer is B % by weight, $A-B \geq 2 B$ may be satisfied.

FIG. 1 illustrates a stacking sequence of the organic material layer of the organic electroluminescent device according to the exemplary embodiment. According to FIG. 1, the anode, the first organic material layer, the light emitting layer, the second organic material layer, and the cathode are sequentially stacked on a substrate. FIG. 1 illustrates an example in which the anode is provided on the substrate, but the case where the cathode is provided on the substrate is also included in a range of the exemplary embodiment described in the present specification. For example, the organic electroluminescent device described in the present specification may have a structure in which the cathode, the second organic material layer, the light emitting layer, the first organic material layer, and the anode are sequentially stacked on the substrate.

In general, in an organic electroluminescent device, electrons are injected and transported from a cathode to a light emitting layer, and holes are injected and transported from an anode to the light emitting layer. Accordingly, in the organic electroluminescent device of the related art, an n-type organic material layer, in which electrons are injected or transported through the LUMO energy level, is disposed between the cathode and the light emitting layer.

It is opposite to the technology, which has been thought in the field of the organic electroluminescent device, that an organic material layer including a p-type dopant is disposed as the organic material layer associated with the cathode. However, according to the description of the present specification, the second organic material layer including the p-type dopant is disposed as the organic material layer associated with the cathode.

In the device illustrated in FIG. 1, a method of injecting electric charges between the cathode and the second organic material layer associated with the cathode will be described in more detail as follows.

In the organic electroluminescent device in the related art including the n-type organic material layer as the organic material layer associated with the cathode, a barrier for injecting electrons from the cathode is a difference between the work function of the cathode and the LUMO energy level of the n-type organic material layer. In the organic electroluminescent device in the related art, electrons need to overcome the electron injection barrier corresponding to the difference between the work function of the cathode and the LUMO energy level of the n-type organic material layer in order to move from the work function of the cathode to the LUMO energy level of the n-type organic material layer. Accordingly, in the structure of the organic electroluminescent device in the related art, in order to reduce the electron injection barrier, an electron injection layer such as an LiF layer is introduced,

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an electron transporting layer is doped with an alkali metal or an alkaline earth metal, or a metal having a low work function is used as a cathode material.

However, according to the exemplary embodiments described in the present specification, holes move toward the cathode through the HOMO energy level of the above-described second organic material layer including the p-type dopant. FIG. 3 illustrates a schematic view of the movement of the electric charge between the cathode and the second organic material layer including the p-type dopant in the organic electroluminescent device described in the present specification, for example, the organic electroluminescent device illustrated in FIG. 1. According to FIG. 3, a hole transported to the HOMO energy level of the second organic material layer including the p-type dopant meets an electron of the cathode and is annihilated. Accordingly, the electron injection barrier is not present between the cathode and the second organic material layer. Therefore, in the organic electroluminescent device described in the present specification, it is not necessary to make an effort to reduce the electron

injection barrier from the cathode to the organic material layer.

Accordingly, according to the description of the present specification, it is possible to select a cathode material from materials having various work functions.

FIG. 1 illustrates a structure in which the anode, the first organic material layer, the light emitting layer, the second organic material layer, and the cathode are in direct contact with each other. However, an organic material layer may be additionally provided between the anode and the first organic material layer, between the first organic material layer and the light emitting layer, between the light emitting layer and the second organic material layer, or between the second organic material layer and the cathode. For example, when an additional organic material layer is provided between the anode and the first organic material layer or between the cathode and the second organic material layer, a p-type organic material layer may be included. A p-type organic material layer may be included between the anode and the first organic material layer, or between the first organic material layer and the light emitting layer, and these may serve as a hole injection or transporting layer.

According to still yet another exemplary embodiment of the present specification, an electron injection or transporting layer may be provided between the light emitting layer and the second organic material layer. Here, the electron injection or transporting layer includes an electron injection layer, an electron transporting layer, or a layer that simultaneously injects or transports electrons. An n-type organic material layer may be provided as the electron injection or transporting layer. In order to differentiate from the additional n-type organic material layer of the present specification, the n-type organic material layer, which is provided between the light emitting layer and the second organic material layer and is in contact with the second organic material layer, is referred to as a first n-type organic material layer.

FIG. 2 illustrates an example of an organic electroluminescent device including the electron injection or transporting layer. FIG. 2 illustrates that the electron injection or electron transporting layer is in contact with the light emitting layer, but an additional organic material layer may be provided between the layers.

In the device illustrated in FIG. 2, a method of injecting electric charges among the cathode, the second organic material layer associated with the cathode, the first n-type organic material layer, and the light emitting layer will be described in more detail as follows.

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According to FIG. 2, the first n-type organic material layer is disposed between the second organic material layer and the light emitting layer. Here, an electric charge may be generated between the second organic material layer including the p-type dopant and the first n-type organic material layer. Among the electric charges generated between the second organic material layer and the first n-type organic material layer, holes move toward the cathode through the HOMO energy level of the second organic material layer. The holes moving through the HOMO energy level of the second organic material layer escape in the direction of the cathode. Furthermore, among the electric charges generated between the second organic material layer and the first n-type organic material layer, electrons move toward the light emitting layer through the LUMO energy level of the first n-type organic material layer.

In the structure as illustrated in FIG. 2, electric charges are generated between the aforementioned second organic material layer including the p-type dopant and the first n-type organic material layer, and a hole among the generated electric charges moves toward the cathode through the HOMO energy level of the second organic material layer. FIG. 4 illustrates a schematic view of the movement of the electric charge in the structure illustrated in FIG. 2.

Meanwhile, the light emitting characteristic in the organic electroluminescent device is one of the important characteristics of the device. In order to efficiently emit light in the organic electroluminescent device, it is important to achieve a charge balance in a light emitting region. For this purpose, electrons transported from the cathode and holes transported from the anode need to achieve a quantitative balance, and a point at which electrons and holes meet each other to form excitons needs to be within the light emitting region.

Meanwhile, in the organic electroluminescent device, it is possible to use a method of controlling a cavity of the device according to a light emitting color as one of the methods of increasing light emitting efficiency. The light emitting efficiency may be further increased by controlling the cavity of the device so as to be suitable for a wavelength of a light emitting color. Here, the cavity of the device means a length within which light may be resonated in the device. In an example, when an upper electrode is a transparent electrode and a lower electrode is a reflective electrode, the cavity of the device may mean a length from a top of the upper electrode to a top of the lower electrode.

In addition, in the organic electroluminescent device, the distance from the light emitting layer to the cathode may also affect light loss by a surface plasmon, a metal, a waveguide mode, a substrate mode, an out-coupled mode, and the like. Accordingly, it may be necessary to adjust the distance from the light emitting layer to the cathode.

In order to control the distance from the cavity or light emitting layer of the device to the cathode thereof as described above, in the structure of the organic electroluminescent device in the related art, when the thickness of the n-type organic material layer associated with the cathode, for example, the electron transporting layer is increased, an imbalance of the electric charges may be caused. However, according to the description of the present specification, in the organic electroluminescent device, it is possible to control the thickness of the second organic material layer associated with the cathode. That is, controlling the thickness of the second organic material layer may be used to control the distance between the cavity or the light emitting device of the device and the cathode. In the exemplary embodiments of the present specification, electrons reaching the light emitting layer are not transported from the cathode, and are generated between

the second organic material layer and the first n-type organic material layer. Accordingly, controlling the thickness of the second organic material layer does not affect the charge balance in the light emitting layer. Furthermore, in the exemplary embodiments of the present invention, when the thickness of the second organic material layer is controlled, it is possible to minimize a problem in that in a structure of the related art, a driving voltage is increased according to the increase in thickness of the electron transporting layer which is an n-type organic material layer.

In the structure of the related art, when a distance (D) from the cathode to the light emitting layer is controlled, the charge balance in the light emitting layer may be affected. The reason is because the amount of electrons reaching the light emitting layer is varied when the thickness of the n-type organic material layer, for example, the electron injection layer or the electron transporting layer is controlled. FIG. 4 illustrates a structure from the cathode to the light emitting layer in the structure of the organic electroluminescent device according to the exemplary embodiments of the present specification as illustrated in FIG. 2. In the structure according to the exemplary embodiments of the present specification, when the thickness D_h of the second organic material layer associated with the cathode is controlled, it may be affected to control the distance from the light emitting point of the light emitting layer to the cathode as a distance related to the cavity of the device, but the charge balance is not affected because the length D_e related to the amount of electrons is not affected. Here, the light emitting point in the light emitting layer means a point at which light is actually emitted according to the balance of electrons and holes. The light emitting point may be varied depending on the material of the light emitting layer. In the art to which the present invention pertains, a central point of the light emitting layer or the interface between the light emitting layer and another layer may be set as the light emitting point.

For example, when the cathode serves as a reflective plate, the distance D from the light emitting point in the light emitting layer to the cathode may be controlled as an integer-fold of [refractive index of the organic material layer $\times \lambda / 4$]. At this time, λ is a wavelength of light emitted from the light emitting layer. Since lights having different colors have different wavelengths, it is possible to differently control the distance D from the light emitting point in the light emitting layer to the cathode depending on the color of light emitting from the light emitting layer. Further, it is possible to differently control the distance D from the light emitting point in the light emitting layer to the cathode depending on the refractive index of the organic material layer. At this time, when the organic material layer is composed of two or more layers, the refractive index of the organic material layer may be calculated by obtaining the refractive index of each layer and then obtaining the sum thereof.

In addition, when light proceeding toward the cathode reaches the surface of the cathode and is reflected, the penetration depth of light is varied depending on the type of cathode material. Accordingly, the type of cathode material causes a change in phase of light reflected from the surface of the cathode. At this time, in consideration of the phase difference to be changed, it is necessary to control the distance D from the light emitting point in the light emitting layer to the cathode. Accordingly, a material of the cathode may also affect the distance from the light emitting layer to the cathode.

When a phase matching of light proceeding from the light emitting layer to the cathode and light reflected from the cathode occurs, a constructive interference occurs, and thus it is possible to implement bright light, and conversely, when a

phase mismatching between the lights occurs, a destructive interference occurs, and thus a part of the light is annihilated. According to the phenomenon of the phase matching and the phase mismatching as described above, the brightness of the emitting light is shown in the form of a sine curve depending on the distance from the light emitting layer to the cathode.

According to an exemplary embodiment of the present specification, in the sine curve showing the brightness of the emitting light of the device according to the distance from the light emitting layer to the cathode, a value of an x-axis at a point where the brightness of light is maximum may be set as the distance from the light emitting layer to the cathode.

According to an exemplary embodiment of the present specification, a distance from a boundary between the second organic material layer and the first n-type organic material layer to the light emitting layer and a distance from the anode to the light emitting layer may be controlled such that an amount of holes in the light emitting layer is balanced with that of electrons therein. Here, the balance between the amount of holes and the amount of electrons means that the holes and electrons injected into the light emitting layer are recombined with each other in the light emitting layer and thus effectively form excitons for light emission, and the loss of holes and electrons involved in forming the excitons is minimized. For example, when the amount of holes in the device is larger than the amount of electrons therein, holes, which do not emit light and are annihilated, are generated in addition to holes involved in excitons due to excessive holes, thereby causing a loss of the quantum efficiency in the device. Conversely, when the amount of electrons is larger than the amount of holes, the loss of electrons may be caused. Accordingly, an attempt has been made to reduce the amounts of holes and electrons, which are annihilated without contributing to light emission, by achieving a quantitative balance of injected holes and electrons.

For example, as means for achieving a quantitative balance between holes and electrons in the light emitting layer, it is also important to control a movement velocity of holes and electrons. When holes are excessively present in the light emitting layer, a balance between holes and electrons may be achieved in the light emitting layer by increasing an injection velocity of electrons. In general, the hole mobility of a material provided between the anode and the light emitting layer, that is, in a second electric charge transporting passage and transporting holes is faster than the electron mobility of a material provided between the cathode and the light emitting layer, that is, in a first electric charge transporting passage and transporting electrons. For example, the hole mobility of NPB is at the level of $8.8 \times 10^{-4} \text{ cm}^2/\text{Vs}$, whereas the electron mobility of Alq3 is at the level of $6.7 \times 10^{-5} \text{ cm}^2/\text{Vs}$.

Accordingly, in order to enhance the light emission efficiency of the device, it is important to enhance the electron mobility, and when increasing and using the distance from the cathode to the light emitting layer, it may be effective to increase the thickness of the second organic material layer rather than the thickness of the first n-type organic material layer.

Therefore, according to an example, the distance from a boundary between the second organic material layer and the first n-type organic material layer to the light emitting layer may be configured to be shorter than the distance from the anode to the light emitting layer. As a specific example, the distance from the boundary between the second organic material layer and the first n-type organic material layer to the light emitting layer may be configured to be from 100 Å to 500 Å. As another specific example, the distance from the anode to the light emitting layer may be configured to be from 500 Å to

5,000 Å. However, the specific value may be controlled differently according to the characteristics of the light emitting layer or the user.

According to an exemplary embodiment of the present specification, it is possible to control the thickness of the second organic material layer for stability of the device. When the thickness of the second organic material layer is controlled to be increased, it is possible to further improve the stability of the device without affecting a charge balance in the device or an increase in voltage.

Here, the stability of the device means a degree which may prevent a short phenomenon due to contact between the anode with the cathode, which may occur when the device is thin. In general, when the thickness of the n-type organic material layer provided between the cathode and the light emitting layer is controlled to be increased, stability of the device may be improved, but driving voltage thereof is rapidly increased, thereby reducing the power efficiency thereof. In order to solve the problem in the related art, an attempt has been made to control the thickness of the n-type organic material layer provided between the cathode and the light emitting layer to be increased and dope the organic material layer with a metal, but there is a problem in that an increase in light absorption efficiency and a reduction in service life occur, and the process thereof becomes complicated.

However, according to the description of the present specification, it is possible to increase the distance between the light emitting layer and the cathode by controlling the thickness of the second organic material layer, which does not affect the charge balance or the increase in voltage, instead of controlling the thickness of the n-type organic material layer provided in the cathode and the light emitting layer. Accordingly, stability of the device is improved, and the increase in driving voltage is minimized, thereby increasing the power efficiency.

According to an example, in consideration of stability of the device, the distance from the cathode to the light emitting layer may be configured to be longer than the distance from the anode to the light emitting layer. Even in such a configuration, the charge balance or the increase in voltage is not affected unlike the related art. In a specific example, the thickness of the second organic material layer may be controlled to be 5 nm or more, and as the second organic material layer becomes thick, the stability of the device may be enhanced. The upper limit of the thickness of the second organic material layer is not particularly limited, and may be determined by those skilled in the art. For example, in consideration of ease of process, the thickness of the second organic material layer may be selected from 500 nm or less.

According to another exemplary embodiment of the present specification, the thickness of the second organic material layer may be controlled such that the cavity length of the organic electroluminescent device is an integer-fold of the wavelength of light emitted from the light emitting layer. It is possible to improve light emission efficiency caused by constructive interference of light by controlling the cavity length of the organic electroluminescent device to be an integer-fold of the wavelength of light as described above.

According to still another exemplary embodiment of the present specification, it is possible to control the distance from the boundary between the second organic material layer and the first n-type organic material layer to the light emitting layer and the distance from the anode to the light emitting layer such that the amount of holes in the light emitting layer is balanced with the amount of electrons therein, and to control the thickness of the second organic material layer such

that the cavity length of the organic electroluminescent device is an integer-fold of the wavelength of light emitted from the light emitting layer.

According to yet another exemplary embodiment of the present specification, it is possible to control a moving time of electrons from the boundary between the second organic material layer and the first n-type organic material layer to the light emitting layer and a moving time of holes from the anode to the light emitting layer such that the holes and the electrons of the device are quantitatively balanced in the light emitting layer, and to control the thickness of the second organic material layer such that the cavity length of the organic electroluminescent device is an integer-fold of the wavelength of light emitted from the light emitting layer.

According to still yet another embodiment of the present specification, a difference between the HOMO energy level of the second organic material layer and the LUMO energy level of the first n-type organic material layer is 2 eV or less. According to an exemplary embodiment of the present specification, the difference between the HOMO energy level of the second organic material layer and the LUMO energy level of the first n-type organic material layer may be more than 0 eV and 2 eV or less, or more than 0 eV and 0.5 eV or less. According to another exemplary embodiment of the present specification, a material for the second organic material layer and the first n-type organic material layer may be selected such that the difference between the HOMO energy level of the second organic material layer and the LUMO energy level of the first n-type organic material layer is from 0.01 eV to 2 eV.

In the case where the energy difference between the HOMO energy level of the second organic material layer and the LUMO energy level of the first n-type organic material layer is 2 eV or less, when the second organic material layer and the first n-type organic material layer are in contact with each other, an NP junction may be easily generated therebetween. In this case, a driving voltage for injecting electrons may be reduced.

As the second organic material layer is in contact with the first n-type organic material layer, an NP junction is formed between the second organic material layer and the first n-type organic material layer. When the NP junction is formed, the difference between the HOMO energy level of the second organic material layer and the LUMO energy level of the first n-type organic material layer is reduced. Accordingly, when an external voltage is applied thereto, holes and electrons are easily formed from the NP junction.

According to an exemplary embodiment of the present specification, the work function of the cathode may have a value equal to or less than the HOMO energy level of the second organic material layer.

When the work function of the cathode has a value equal to or less than the HOMO energy level of the second organic material layer, an injection barrier is not present when electrons are injected from the cathode to the HOMO energy level of the second organic material layer.

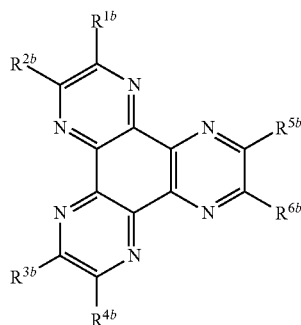
According to an exemplary embodiment of the present specification, the cathode and the second organic material layer may be in contact with each other. When the cathode and the second organic material layer are in contact with each other and the work function of the cathode is equal to or greater than the HOMO energy level of the second organic material layer, electrons are easily injected from the cathode to the HOMO energy level of the first p-type organic material layer even though the difference between the work function of the cathode and the HOMO energy level of the second organic material layer is large. This is because holes produced by the NP

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junction between the second organic material layer and the first n-type organic material layer move along the second organic material layer toward the cathode. In general, when electrons move from the low energy level to the high energy level, there is no barrier. Further, when holes move from the high energy level to the low energy level, no barrier is produced. Accordingly, electrons may move from the cathode to the HOMO energy level of the second organic material layer without an energy barrier.

An additional layer may be additionally provided between the cathode and the second organic material layer. In this case, the HOMO energy level of the additional layer may be equal to the work function of the cathode or the HOMO energy level of the second organic material layer, or may be between the work function of the cathode or the HOMO energy level of the second organic material layer.

In the present specification, the p-type dopant included in the first organic material layer and the second organic material layer may be used without particular limitation as long as the p-type dopant is an electron-acceptor material. However, when a compound of the following Formula 1 is used as the p-type dopant, the driving voltage is reduced and a light scattering effect is caused in the first organic material layer, which is advantageous for enhancing the light extraction effect.



In Formula 1, R^{1b} to R^{6b} may be each hydrogen, a halogen atom, nitrile ($-\text{CN}$), nitro ($-\text{NO}_2$), sulfonyl ($-\text{SO}_2\text{R}$), sulfoxide ($-\text{SOR}$), sulfonamide ($-\text{SO}_2\text{NR}$), sulfonate ($-\text{SO}_3\text{R}$), trifluoromethyl ($-\text{CF}_3$), ester ($-\text{COOR}$), amide ($-\text{CONHR}$ or $-\text{CONRR}'$), a substituted or unsubstituted straight or branched C_1 to C_{12} alkoxy, a substituted or unsubstituted straight or branched C_1 to C_{12} alkyl, a substituted or unsubstituted straight or branched C_2 to C_{12} alkenyl, a substituted or unsubstituted aromatic or non-aromatic heterocyclic ring, a substituted or unsubstituted aryl, a substituted or unsubstituted mono- or di-aryl amine, or a substituted or unsubstituted aralkyl amine, in which R and R' are each a substituted or unsubstituted C_1 to C_{60} alkyl, a substituted or unsubstituted aryl, or a substituted or unsubstituted 5- to 7-membered heterocyclic ring.

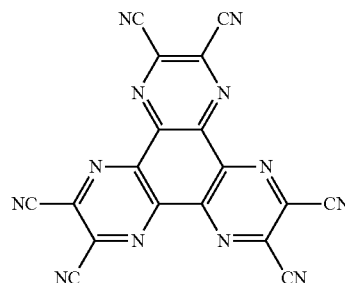
In the description, the "substituted or unsubstituted" means to be unsubstituted or substituted with a halogen atom, nitrile ($-\text{CN}$), nitro ($-\text{NO}_2$), sulfonyl ($-\text{SO}_2\text{R}$), sulfoxide ($-\text{SOR}$), sulfonamide ($-\text{SO}_2\text{NR}$), sulfonate ($-\text{SO}_3\text{R}$), trifluoromethyl ($-\text{CF}_3$), ester ($-\text{COOR}$), amide ($-\text{CONHR}$ or $-\text{CONRR}'$), a straight or branched C_1 to C_{12} alkoxy, a straight or branched C_1 to C_{12} alkyl, a straight or branched C_2 to C_{12} alkenyl, an aromatic or non-aromatic heterocyclic ring, an aryl, a mono- or di-aryl amine, or an aralkyl amine, in

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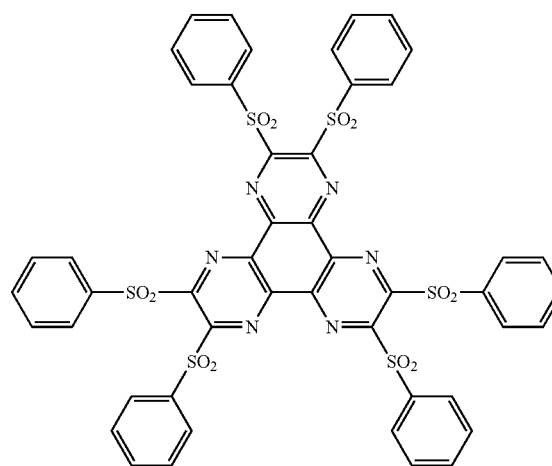
which R and R' are each a C_1 to C_{60} alkyl, an aryl, or a 5- to 7-membered heterocyclic ring.

The compound of Formula 1 may be exemplified as compounds of the following Formulas 1-1 to 1-6.

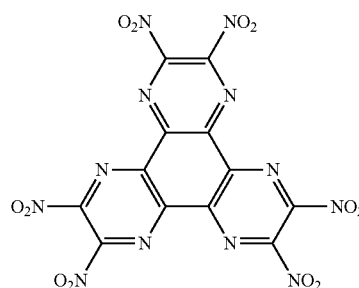
[Formula 1-1]



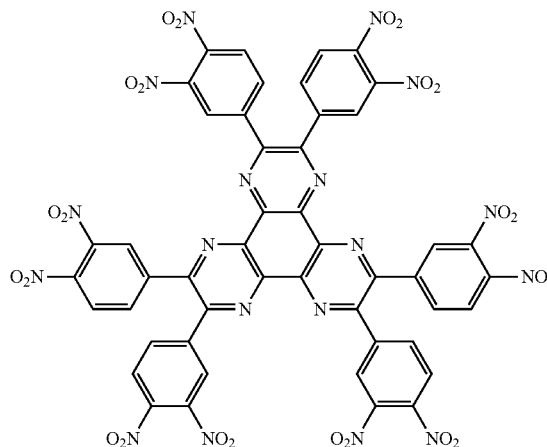
[Formula 1-2]



[Formula 1-3]



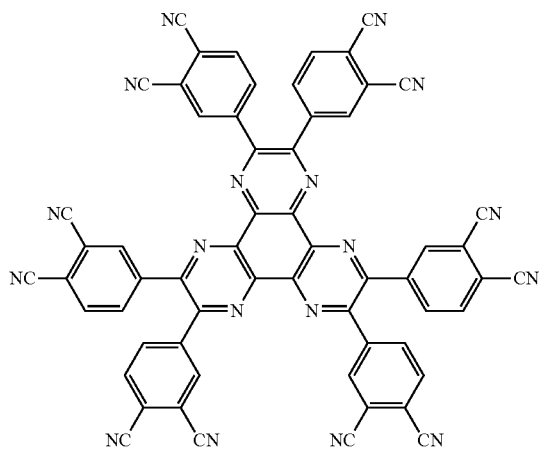
[Formula 1-4]



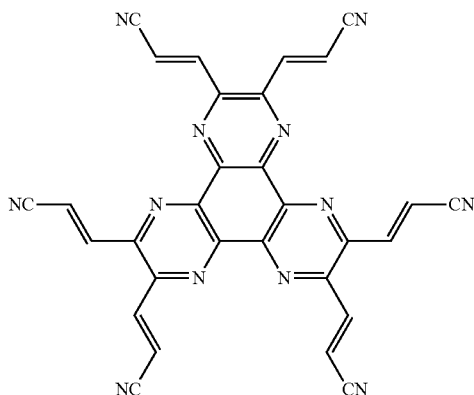
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[Formula 1-5]

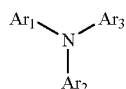


[Formula 1-6]



Other examples, or synthesis methods and various characteristics of Formula 1 are described in US Patent Application No. 2002-0158242, and U.S. Pat. Nos. 6,436,559 and 4,780,536, and the contents of these documents are all incorporated in the present specification.

In the first organic material layer and the second organic material layer, a p-type organic material may be used as the organic material doped with the p-type dopant. As a specific example of the p-type organic material, an aryl amine compound may be used. As an example of the aryl amine compound, there is a compound of the following Formula 2.



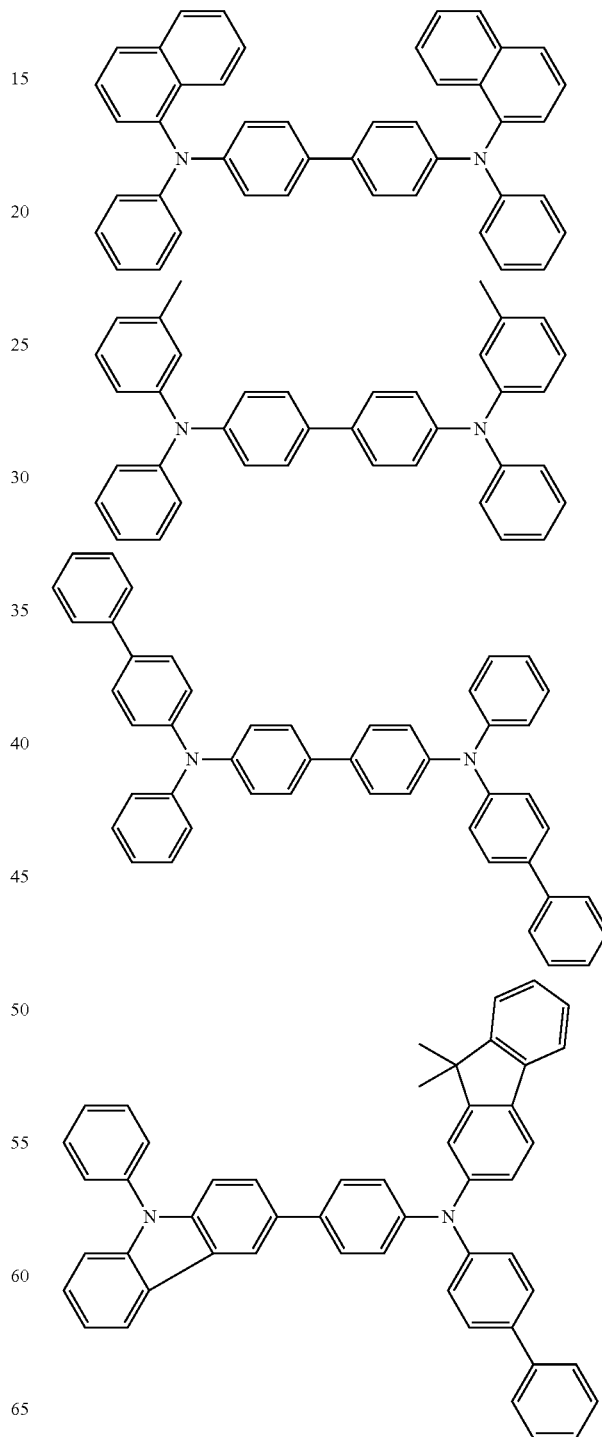
[Formula 2]

In Formula 2, Ar₁, Ar₂, and Ar₃ are each independently hydrogen or a hydrocarbon group. At this time, at least one of

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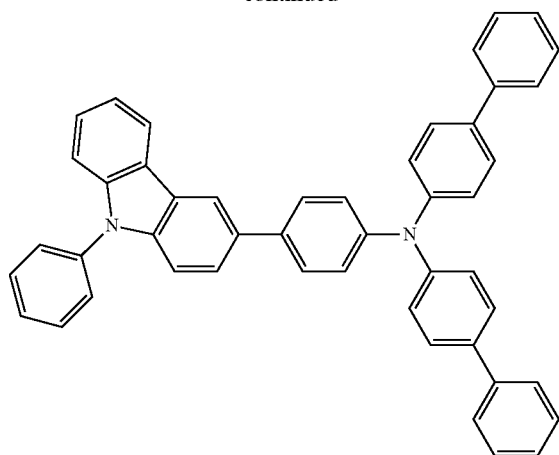
Ar₁, Ar₂, and Ar₃ may include an aromatic hydrocarbon substitute, and substitutes may be the same as each other, and may be composed of different substitutes. Those which are not an aromatic hydrocarbon among Ar₁, Ar₂, and Ar₃ may be hydrogen; a straight, branched, or cyclic aromatic hydrocarbon; and a heterocyclic group including N, O, S, or Se.

Specific examples of Formula 2 include the following formulas, but the range of exemplary embodiments described in the present specification is not always limited thereto.



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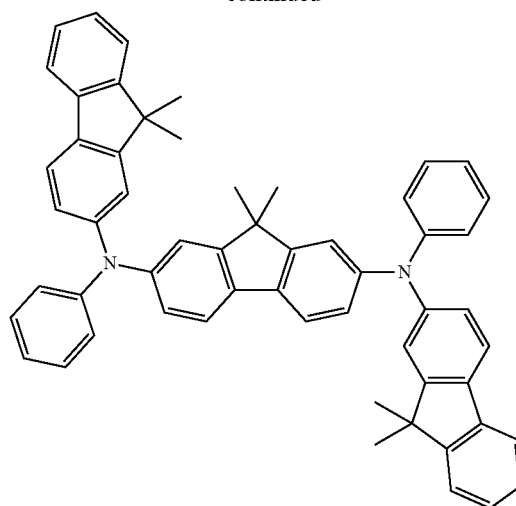
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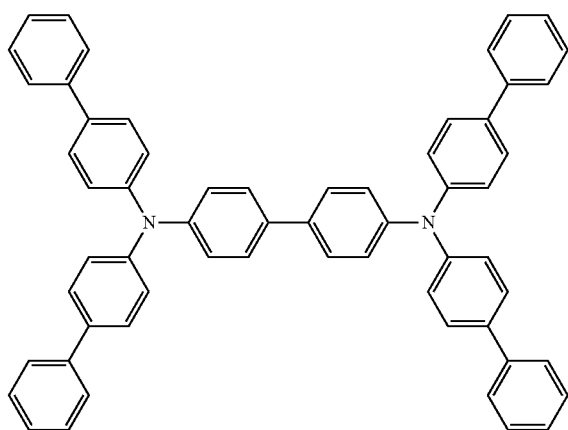
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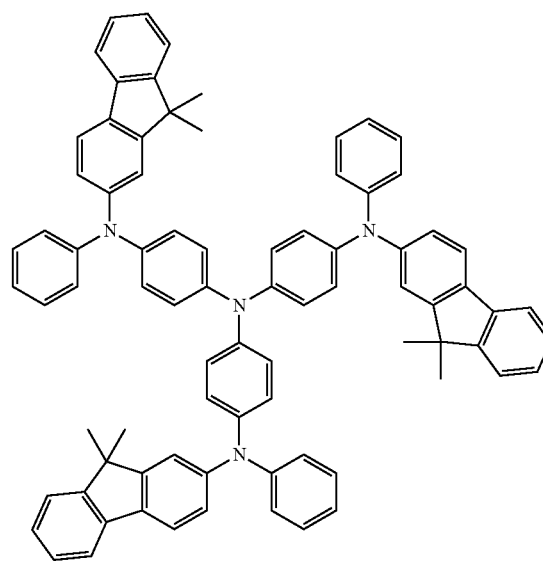


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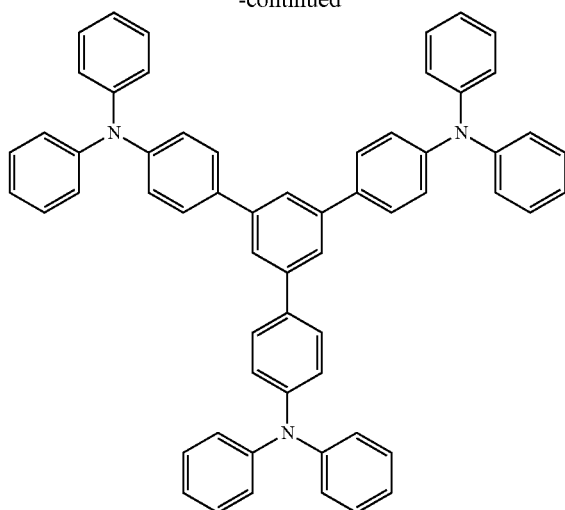
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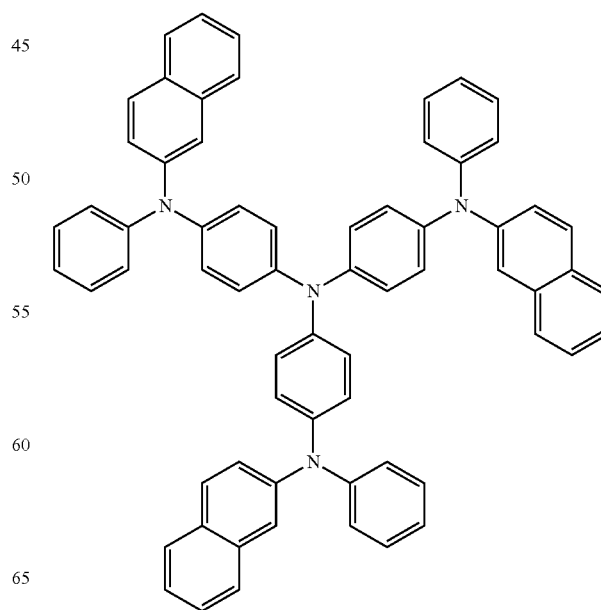
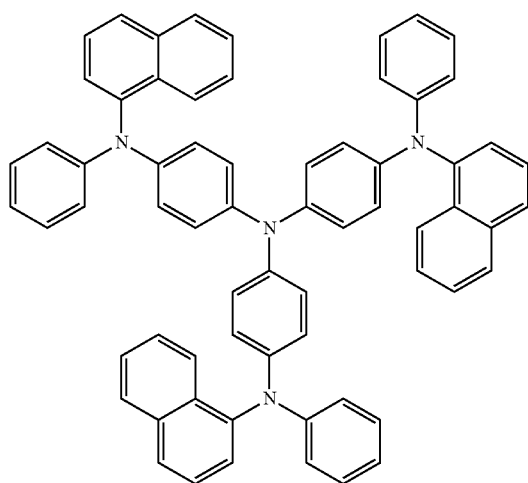
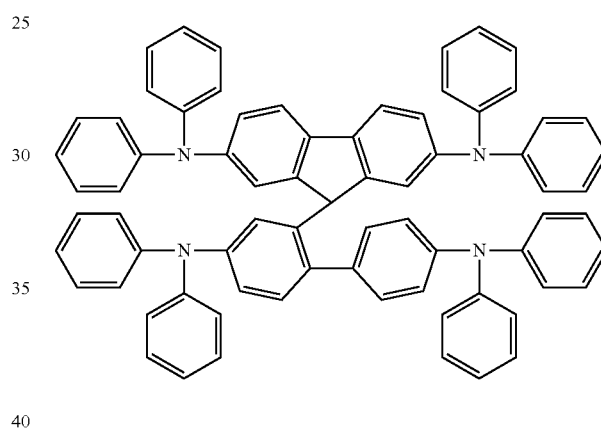
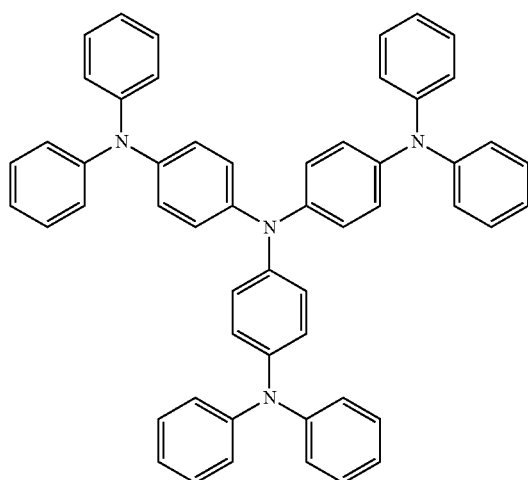
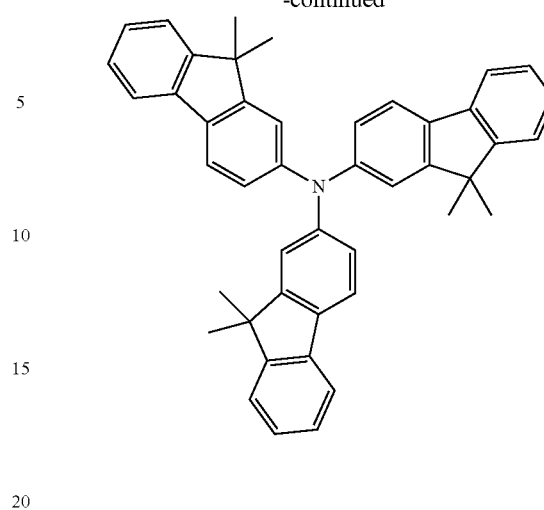


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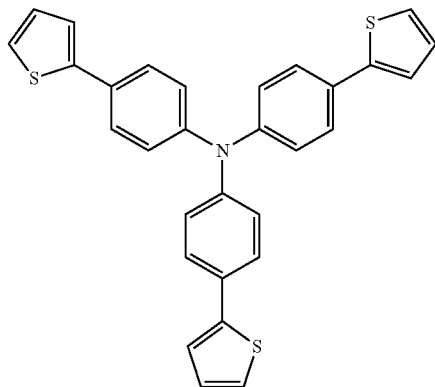
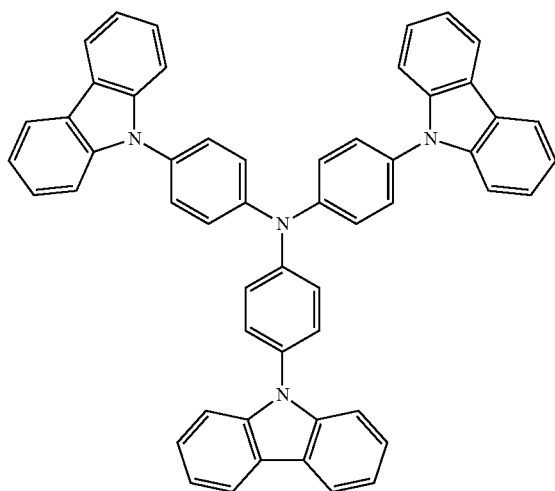
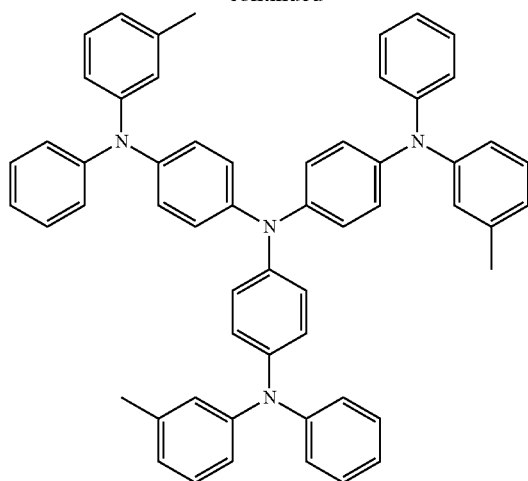
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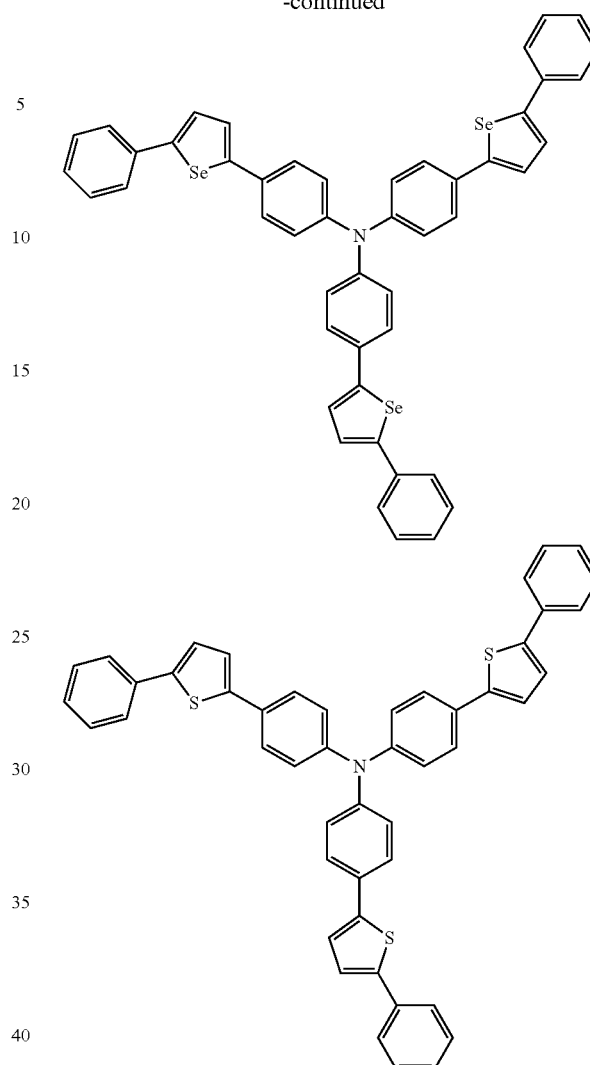


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According to another exemplary embodiment of the present specification, when the p-type dopant in the second organic material layer is the compound of Formula 1 and the material doped with the p-type dopant is the compound of Formula 2, for example, NPB, the weight ratio of the compound of Formula 1 and the compound of Formula 2 may be controlled to be from 1:9 to 5:5, specifically, from 2:8 to 4:6. The range is advantageous for enhancing the light extraction effect caused by light scattering.

The first n-type organic material layer is not limited to be composed of a single material, and may be composed of one or two or more compounds having n-type semiconductor characteristics. In addition, the first n-type organic material layer may be composed of a single layer, but may also include two or three or more layers. At this time, the two or more layers may be composed of the same material, but may be composed of different materials. If necessary, at least one layer of the layers constituting the first n-type organic material layer may be doped with an n-type dopant.

The first n-type organic material layer is not particularly limited as long as the organic material layer is composed of a material which may move electric charges through the LUMO energy level between the second organic material layer and the light emitting layer, as described above. For

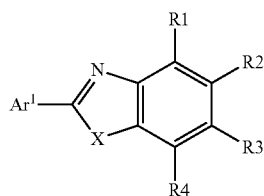
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example, the first n-type organic material layer may include one or more compounds selected from the compound of Formula 1, or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4TCNQ), fluoro-substituted 3,4,9,10-perylene-tetracarboxylic dianhydride (PTCDA), cyano-substituted 3,4,9,10-perylene-tetracarboxylic dianhydride (PTCDA), naphthalene tetracarboxylic dianhydride (NTCDA), fluoro-substituted naphthalene tetracarboxylic dianhydride (NTCDA), and cyano-substituted naphthalene tetracarboxylic dianhydride (NTCDA).

According to an exemplary embodiment of the present specification, the first n-type organic material layer may be formed of the same material as the p-type dopant of the second organic material layer.

Moreover, as a material for the first n-type organic material layer, it is possible to use an organic material having n-type semiconductor characteristics used as an electron injection or transporting material, which is known in the art. Specifically, the following material may be used, but the present invention is not limited thereto. For example, as an example of the material for the first n-type organic material layer, it is possible to use a compound having a functional group selected from an imidazole group, an oxazole group, a thiazole group, a quinoline group, and a phenanthroline group.

Specific examples of the compound having a functional group selected from an imidazole group, an oxazole group, and a thiazole group include a compound of the following Formula 3 or 4.

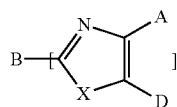


[Formula 3]

In Formula 3, R¹ to R⁴ may be the same as or different from each other, are each independently a hydrogen atom; a C₁ to C₃₀ alkyl group which is unsubstituted or substituted with one or more groups selected from the group consisting of a halogen atom, an amino group, a nitrile group, a nitro group, a C₁ to C₃₀ alkyl group, a C₂ to C₃₀ alkenyl group, a C₁ to C₃₀ alkoxy group, a C₃ to C₃₀ cycloalkyl group, a C₃ to C₃₀ heterocycloalkyl group, a C₅ to C₃₀ aryl group, and a C₂ to C₃₀ heteroaryl group; a C₃ to C₃₀ cycloalkyl group which is unsubstituted or substituted with one or more groups selected from the group consisting of a halogen atom, an amino group, a nitrile group, a nitro group, a C₁ to C₃₀ alkyl group, a C₂ to C₃₀ alkenyl group, a C₁ to C₃₀ alkoxy group, a C₃ to C₃₀ cycloalkyl group, a C₃ to C₃₀ heterocycloalkyl group, a C₅ to C₃₀ aryl group, and a C₂ to C₃₀ heteroaryl group; a C₅ to C₃₀ aryl group which is unsubstituted or substituted with one or more groups selected from the group consisting of a halogen atom, an amino group, a nitrile group, a nitro group, a C₁ to C₃₀ alkyl group, a C₂ to C₃₀ alkenyl group, a C₁ to C₃₀ alkoxy group, a C₃ to C₃₀ cycloalkyl group, a C₃ to C₃₀ heterocycloalkyl group, a C₅ to C₃₀ aryl group, and a C₂ to C₃₀ heteroaryl group; or a C₂ to C₃₀ heteroaryl group which is unsubstituted or substituted with one or more groups selected from the group consisting of a halogen atom, an amino group, a nitrile group, a nitro group, a C₁ to C₃₀ alkyl group, a C₂ to C₃₀ alkenyl group, a C₁ to C₃₀ alkoxy group, a C₃ to C₃₀ cycloalkyl group, a C₃ to C₃₀ heterocycloalkyl group, a C₅ to C₃₀ aryl group, and a C₂ to C₃₀ heteroaryl group.

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C₃₀ aryl group, and a C₂ to C₃₀ heteroaryl group, and may form an aliphatic, aromatic, aliphatic hetero, or aromatic hetero condensation ring or a spiro bond in conjunction with an adjacent group; Ar¹ is a hydrogen atom, a substituted or unsubstituted aromatic ring, or a substituted or unsubstituted aromatic heterocyclic ring; X is O, S, or NR^a; and R^a may be hydrogen, a C₁ to C₇ aliphatic hydrocarbon, an aromatic ring, or an aromatic heterocyclic ring.

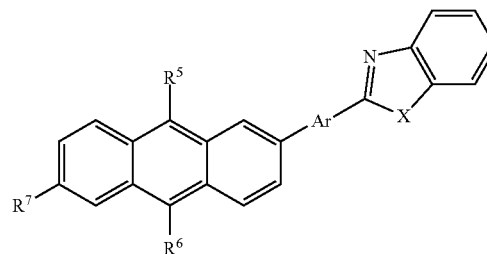


[Formula 4]

In Formula 4, X is O, S, NR^b, or a C₁ to C₇ divalent hydrocarbon group; A, D, and R^b are each hydrogen, a nitrile group (—CN), a nitro group (—NO₂), a C₁ to C₂₄ alkyl, a substituted aromatic ring including a C₅ to C₂₀ aromatic ring or a hetero atom, a halogen, or an alkylene or an alkylene including a hetero atom that may form a fused ring in conjunction with an adjacent ring; A and D may be connected to each other to form an aromatic or hetero aromatic ring; B is a substituted or unsubstituted alkylene or arylene which conjugately or unconjugately connects multiple heterocyclic rings as a linkage unit when n is 2 or more, and a substituted or unsubstituted alkyl or aryl when n is 1; and n is an integer from 1 to 8.

Examples of the compound of Formula 4 include compounds known in Korean Patent Application Laid-Open No. 2003-006773, and examples of the compound of Formula 4 include compounds described in U.S. Pat. No. 5,645,948 and compounds described in WO05/097756. All the contents of the documents are incorporated in the present specification.

Specifically, the compound of Formula 3 also includes the compound of Formula 5.

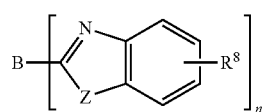


[Formula 5]

In Formula 5, R⁵ to R⁷ are the same as or different from each other, and are each independently a hydrogen atom, a C₁ to C₂₀ aliphatic hydrocarbon, an aromatic ring, an aromatic heterocyclic ring, or an aliphatic or aromatic fused ring; Ar is a direct bond, an aromatic ring or an aromatic heterocyclic ring; X is O, S, or NR^a; R^a is a hydrogen atom, a C₁ to C₇ aliphatic hydrocarbon, an aromatic ring, or an aromatic heterocyclic ring; and however, the case where R⁵ and R⁶ are simultaneously hydrogen is ruled out.

Further, the compound of Formula 4 also includes the following compound of Formula 6.

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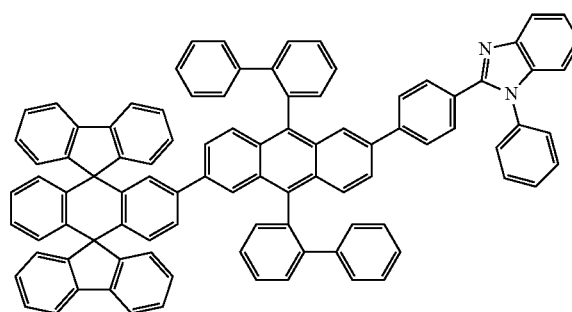
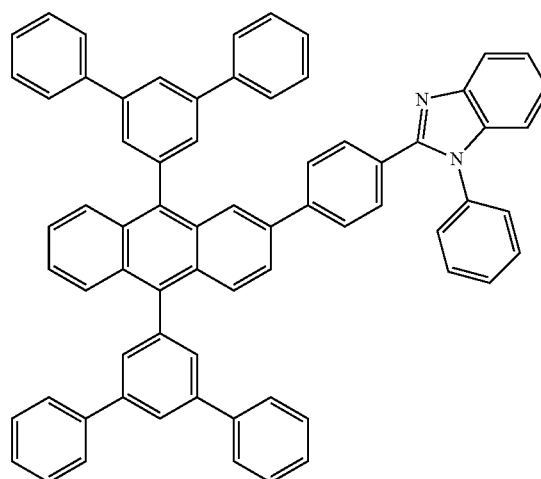
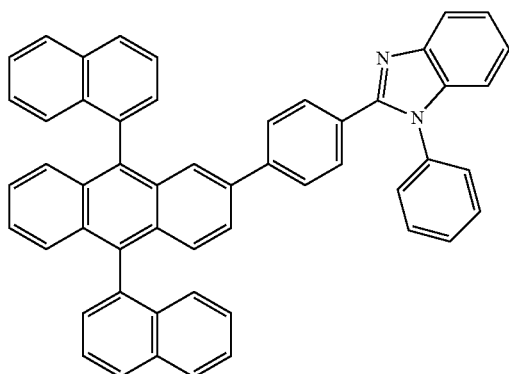
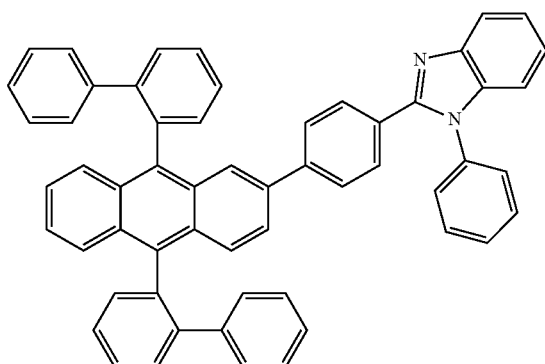
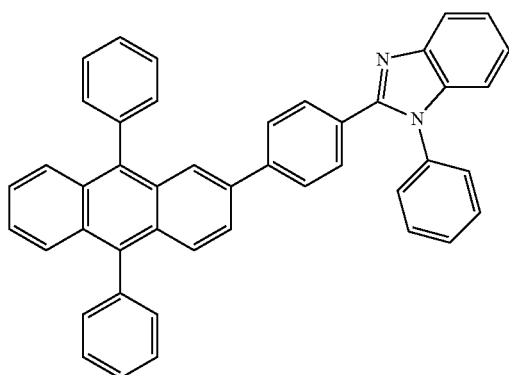
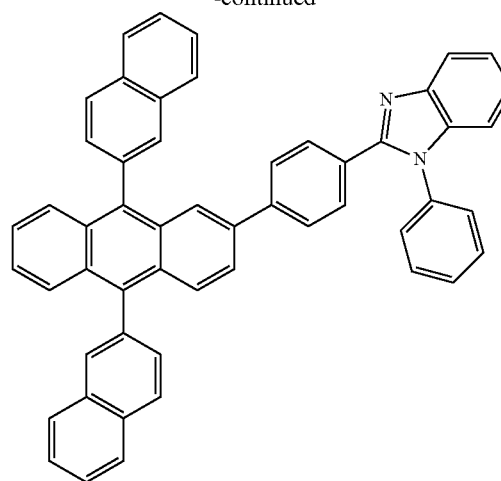
[Formula 6]

In Formula 6, Z is O, S, or NR^b; R⁸ and R^b are a hydrogen atom, a C₁ to C₂₄ alkyl, a substituted aromatic ring including a C₅ to C₂₀ aromatic ring or a hetero atom, a halogen, or an alkylene or an alkylene including a hetero atom which may form a fused ring in conjunction with a benzazole ring; B is alkylene, arylene, a substituted alkylene, or a substituted arylene which conjugately or unconjugately connects multiple benzazoles as a linkage unit when n is 2 or more, and a substituted or unsubstituted alkyl or aryl when n is 1; and n is an integer from 1 to 8.

For example, imidazole compounds having the following structures may be used:

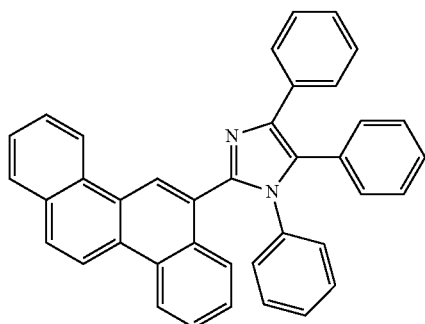
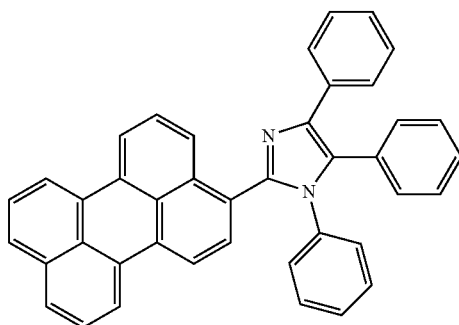
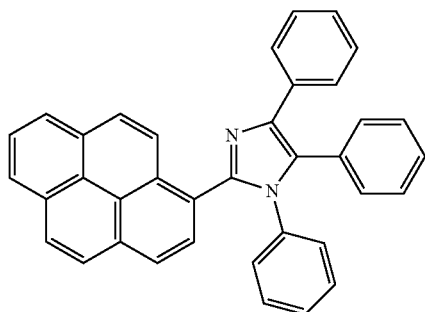
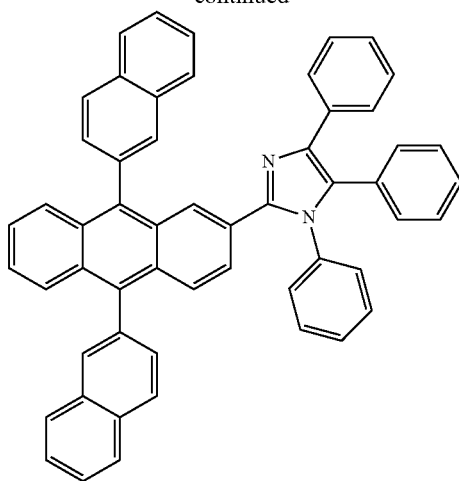
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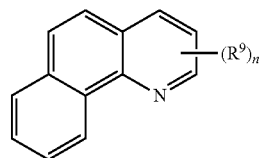


Examples of the compound having a quinoline group include compounds of the following Formulas 7 to 13.

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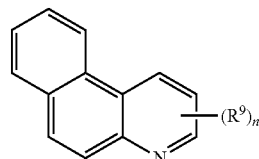
[Formula 7]

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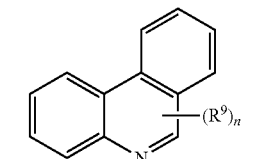
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[Formula 8]



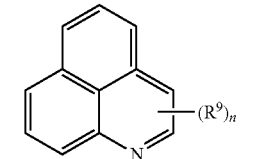
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[Formula 9]



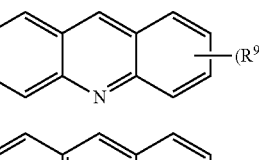
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[Formula 10]



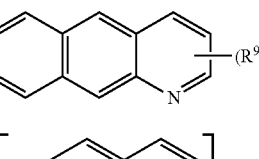
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[Formula 11]



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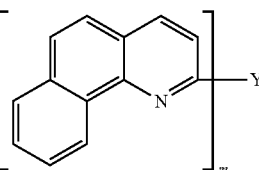
[Formula 12]



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[Formula 13]

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In Formulas 7 to 13,

n is an integer from 0 to 9, m is an integer of 2 or more,

R^9 is selected from a ring structure with hydrogen, an alkyl group such as a methyl group and an ethyl group, a cycloalkyl group such as cyclohexyl and norbornyl, an aralkyl group such as a benzyl group, an alkenyl group such as a vinyl group and an allyl group, a cycloalkenyl group such as a cyclopentadienyl group and a cyclohexenyl group, an alkoxy group such as a methoxy group, an alkylthio group in which an oxygen atom with an ether bond of an alkoxy group is substituted with a sulfur atom, an aryl ether group such as a phenoxy group, an aryl thioether group in which an oxygen atom with an ether bond of an aryl ether group is substituted with a sulfur atom, an aryl group such as a phenyl group, a naphthyl group, and a biphenyl group, a heterocyclic group such as a furyl group, a thienyl group, an oxazolyl group, a pyridyl group, a quinolyl group, and a carbazolyl group, a halogen, a cyano group, an aldehyde group, a carbonyl group, a carboxyl group, an ester group, a carbamoyl group, an amino group, a nitro group, a silyl group such as a trimethylsilyl group, a siloxanyl group

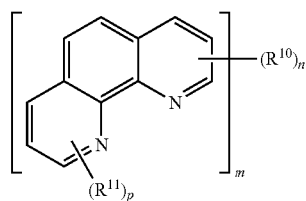
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which is a group having silicon through an ether bond, and an adjacent substituent; and the substituents may be unsubstituted or substituted, and may be the same as or different from each other when n is 2 or more; and

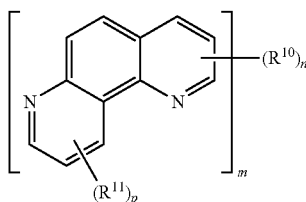
Y is a divalent group of groups of R⁹.

The compounds of Formulas 7 to 13 are described in Korean Patent Application Laid-Open No. 2007-0118711, and the contents of the documents are all incorporated in the present specification by reference.

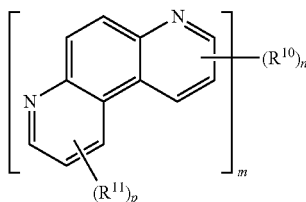
Examples of the compound having a phenanthroline group include the following compounds of Formulas 14 to 24, but are not limited thereto.



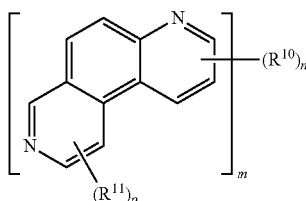
[Formula 14]



[Formula 15]



[Formula 16]



[Formula 17]

In Formulas 14 to 17,

m is an integer of 1 or more, n and p are an integer, n+p is 8 or less,

when m is 1, R¹⁰ and R¹¹ are selected from a ring structure with hydrogen, an alkyl group such as a methyl group and an ethyl group, a cycloalkyl group such as cyclohexyl and norbornyl, an aralkyl group such as a benzyl group, an alkenyl group such as a vinyl group and an allyl group, a cycloalkenyl group such as a cyclopentadienyl group and a cyclohexenyl group, an alkoxy group such as a methoxy group, an alkylthio group in which an oxygen atom with an ether bond of an alkoxy group is substituted with a sulfur atom, an aryl ether group such as a phenoxy group, an aryl thioether group in which an oxygen atom with an ether bond of an aryl ether group is substituted with a sulfur atom, an aryl group such as a phenyl group, a naphthyl group, and a biphenyl group, a heterocyclic group such as a furyl group, a thienyl group, an

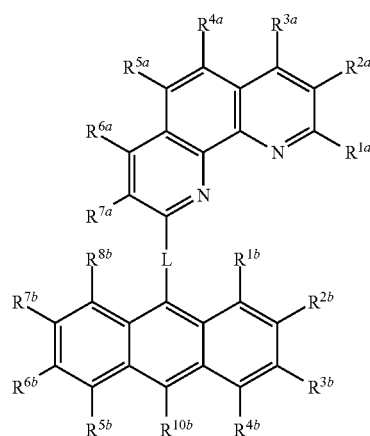
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oxazolyl group, a pyridyl group, a quinolyl group, and a carbazolyl group, a halogen, a cyano group, an aldehyde group, a carbonyl group, a carboxyl group, an ester group, a carbamoyl group, an amino group, a nitro group, a silyl group such as a trimethylsilyl group, a siloxanyl group which is a group having silicon through an ether bond, and an adjacent substituent;

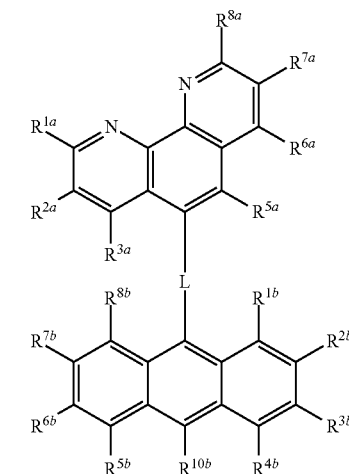
when m is 2 or more, R¹⁰ is a direct bond or a divalent or more group of the above-described groups, and R¹¹ is the same as the case where m is 1, and

the substituents may be unsubstituted or substituted, and when n or p is 2 or more, the substituents may be the same as or different from each other.

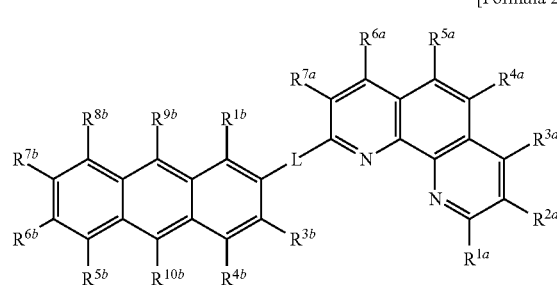
The compounds of Formulas 15 to 18 are described in Korean Patent Application Laid-Open Nos. 2007-0052764 and 2007-0118711, and the contents of the documents are all incorporated in the present specification by reference.



[Formula 18]



[Formula 19]

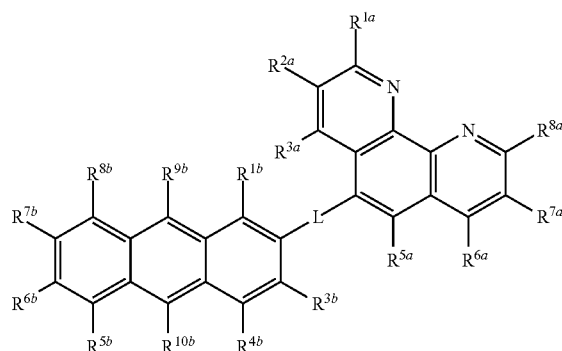


[Formula 20]

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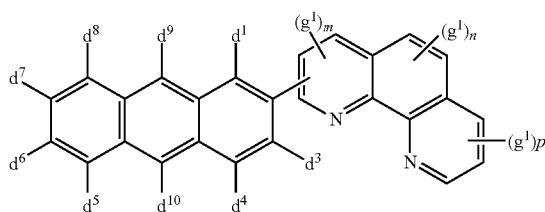
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[Formula 21]

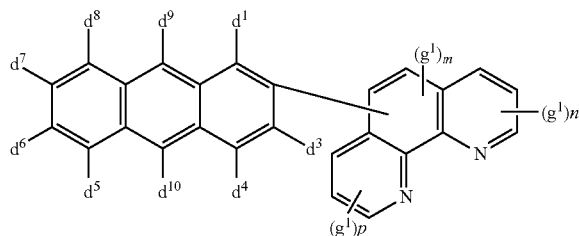


In Formulas 18 to 21, R^{1a} to R^{8a} and R^{1b} to R^{10b} are each a hydrogen atom, a substituted or unsubstituted aryl group having from 5 to 60 nucleus atoms, a substituted or unsubstituted pyridyl group, a substituted or unsubstituted quinolyl group, a substituted or unsubstituted alkyl group having from 1 to 50 carbon atoms, a substituted or unsubstituted cycloalkyl group having from 3 to 50 carbon atoms, a substituted or unsubstituted aralkyl group having from 6 to 50 nucleus atoms, a substituted or unsubstituted alkoxy group having from 1 to 50 carbon atoms, a substituted or unsubstituted aryloxy group having from 5 to 50 nucleus atoms, a substituted or unsubstituted arylthio group having from 5 to 50 nucleus atoms, a substituted or unsubstituted alkoxycarbonyl group having from 1 to 50 carbon atoms, an amino group substituted with a substituted or unsubstituted aryl group having from 5 to 50 nucleus atoms, a halogen atom, a cyano group, a nitro group, a hydroxyl group, or a carboxyl group, and may be bonded to each other to form an aromatic ring, and L is a substituted or unsubstituted arylene group having from 6 to 60 carbon atoms, a substituted or unsubstituted pyridinylene group, a substituted or unsubstituted quinolynylene group, or a substituted or unsubstituted fluorenylene group. The compounds of Formulas 18 to 21 are described in Japanese Patent Application Laid-Open No. 2007-39405, and the content of the document is all incorporated in the present specification by reference.

[Formula 22]



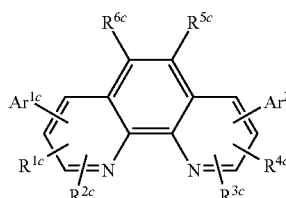
[Formula 23]



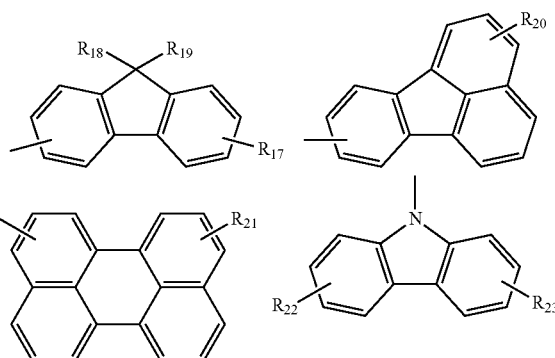
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In Formulas 22 and 23, d¹, d³ to d¹⁰, and g¹ are each hydrogen, or an aromatic or aliphatic hydrocarbon group, m and n are an integer from 0 to 2, and p is an integer from 0 to 3. The compounds of Formulas 22 and 23 are described in US Patent Publication No. 2007/0122656, and the content of the document is all incorporated in the present specification by reference.

[Formula 24]



In Formula 24, R^{1c} to R^{6c} are each a hydrogen atom, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aralkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted heterocyclic group, or a halogen atom, and Ar^{1c} and Ar^{2c} are each selected from the following structural formulas.



In the structural formulas, R₁₇ to R₂₃ are each a hydrogen atom, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aralkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted heterocyclic group, or a halogen atom. The compound of Formula 24 is described in Japanese Patent Application Laid-Open No. 2004-107263, and the content of the document is all incorporated in the present specification by reference.

At least one organic material layer may be further included between the first n-type organic material layer and the light emitting layer. An electron transporting layer, a hole blocking layer, and the like having one or two or more layers may be provided between the first n-type organic material layer and the light emitting layer.

Hereinafter, each layer constituting the organic electroluminescent device described in the present specification will be described in detail. Materials of each layer to be described below may be a single material or a mixture of two or more materials.

Anode

An anode includes a metal, a metal oxide, or a conductive polymer. The conductive polymer may include an electrically conductive polymer. For example, the anode may have a work function value from about 3.5 eV to about 5.5 eV. Examples of exemplary conductive materials include carbon, alumi-

num, vanadium, chromium, copper, zinc, silver, gold, other metals, and an alloy thereof; zinc oxide, indium oxide, tin oxide, indium tin oxide (ITO), indium zinc oxide, and other similar metal oxides; a mixture of oxide and metal such as ZnO:Al and SnO₂:Sb, and the like. As a material for the anode, a transparent material or an opaque material may be used. In the case of a structure in which light is emitted in the anode direction, the anode may be transparently formed. Here, transparency is sufficient as long as light emitted from an organic material layer may be transmitted, and the transmittance of light is not particularly limited.

For example, when the organic electroluminescent device according to the present specification is a top emission type, and the anode is formed on the substrate before the organic material layer and the cathode are formed, an opaque material having excellent optical reflectance may also be used as a material for the anode in addition to a transparent material. For example, when the organic electroluminescent device according to the present specification is a bottom emission type, and the anode is formed on the substrate before the organic material layer and the cathode are formed, as a material for the anode, a transparent material is used, or an opaque material needs to be formed as a thin film enough to be transparent.

Hole Injection or Transporting Layer

In the organic electroluminescent device according to the description of the present specification, an additional p-type organic material layer may be included between the anode and the first organic material layer, or between the first organic material layer and the light emitting layer. The additional p-type organic material layer may be a hole injection layer (HIL) or a hole transporting layer (HTL). The additional p-type organic material layer may include an aryl amine compound, a conductive polymer, or a block copolymer having both a conjugated portion and an unconjugated portion, and the like, but is not limited thereto. As the material of the additional p-type organic material layer, it is possible to use materials exemplified as the material with which the first or second organic material layer is doped.

A fourth n-type organic material layer may be provided between the first organic material layer and the anode. Here, the difference between the HOMO energy level of the first organic material layer and the LUMO energy level of the fourth n-type organic material layer may be 2 eV or less, or 1 eV or less, for example, about 0.5 eV. The first organic material layer and the fourth n-type organic material layer may be in contact with each other. Accordingly, the first organic material layer and the fourth n-type organic material layer may form an NP junction.

The difference between the LUMO energy level of the fourth n-type organic material layer and the work function of the anode may be 4 eV or less. The fourth n-type organic material layer and the anode may be in contact with each other.

The fourth n-type organic material layer may have a LUMO energy level from about 4 eV to about 7 eV, and an electron mobility from about 10⁻⁸ cm²/Vs to 1 cm²/Vs, or from about 10⁻⁶ cm²/Vs to about 10⁻² cm²/Vs. The fourth n-type organic material layer having an electric mobility within the range is advantageous for efficient injection of holes.

The fourth n-type organic material layer may also be formed of a material which may be vacuum deposited, or a material which may be thin-film molded by a solution process. Specific examples of the fourth n-type organic material include the compound of Formula 1 in addition to 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4TCNQ),

fluoro-substituted 3,4,9,10-perylenetetracarboxylic dianhydride (PTCDA), cyano-substituted PTCDA, naphthalene tetracarboxylic dianhydride (NTCDA), fluoro-substituted NTCDA, cyano-substituted NTCDA, or hexanitrile hexaazatriphenylene (HAT), but are not limited thereto.

When the fourth n-type organic material layer and the first organic material layer form an NP junction, holes formed by the NP junction are transported to the light emitting layer through the first organic material layer. As the material for the fourth n-type organic material layer and the p-type dopant of the first organic material layer, the same material may be used.

Light Emitting Layer (EML)

In the light emitting layer, hole transfer and electron transfer occur at the same time, and thus the light emitting layer may have both n-type characteristics and p-type characteristics. For convenience, when electron transport is faster than hole transport, the light emitting layer may be defined as an n-type light emitting layer, and when hole transport is faster than electron transport, the light emitting layer may be defined as a p-type light emitting layer.

The n-type light emitting layer includes aluminum tris(8-hydroxy quinoline) (Alq₃); 8-hydroxy quinoline beryllium (BALq); a benzoxazole-based compound, a benzthiazole-based compound or benzimidazole-based compound; a polyluorene-based compound; a sila cyclopentadiene (silole)-based compound, and the like, but is not limited thereto.

The p-type light emitting layer includes a carbazole-based compound; an anthracene-based compound; a polyphenylenevinylene (PPV)-based polymer; or a spiro compound, and the like, but is not limited thereto.

Electron Injection or Transporting Layer (ETL)

In the present specification, the first n-type organic material layer may also serve as an electron injection or transporting layer. Additionally, an additional second n-type organic material layer may also be provided between the first n-type organic material layer and the light emitting layer. The second n-type organic material layer may also serve as an electron transporting layer or a hole blocking layer. It is preferred that a material for the second n-type organic material layer is a material having a large electron mobility so as to transport electrons well. A third n-type organic material layer may also be provided between the second n-type organic material layer and the light emitting layer. The third n-type organic material layer may also serve as an electron transporting layer or a hole blocking layer.

It is preferred that the first n-type organic material layer is composed of a material having 2 eV or less in difference between the LUMO energy level thereof and the HOMO energy level of the second organic material layer, as described above. According to an example, the first n-type organic material layer may have a LUMO energy level from 5 eV to 7 eV.

It is preferred that the second n-type organic material layer has a LUMO energy level smaller than the LUMO energy level of the first n-type organic material layer. According to an example, the second n-type organic material layer may have a LUMO energy level from 2 eV to 3 eV. According to an example, the second n-type organic material layer may have a HOMO energy level from 5 eV to 6 eV, specifically, from 5.8 eV to 6 eV.

The second or third n-type organic material layer includes aluminum tris(8-hydroxy quinoline) (Alq₃); an organic compound including an Alq₃ structure; a hydroxyflavone-metal complex or a sila cyclopentadiene (silole)-based compound, and the like, but is not limited thereto. As a material for the second or third n-type organic material layer, the aforementioned

tioned material for the first n-type organic material layer may also be used. The second or third n-type organic material layer may be doped with an n-type dopant. According to an exemplary embodiment, when any one of the second n-type organic material layer and the third n-type organic material layer is doped with the n-type dopant, a host material of the doped layer and a material of the undoped layer may be the same as each other.

The n-type dopant may be an organic material or an inorganic material. When the n-type dopant is an inorganic material, the n-type dopant may include an alkali metal, for example, Li, Na, K, Rb, Cs, or Fr; an alkaline earth metal, for example, Be, Mg, Ca, Sr, Ba, or Ra; a rare earth metal, for example, La, Ce, Pr, Nd, Sm, Eu, Tb, Th, Dy, Ho, Er, Em, Gd, Yb, Lu, Y, or Mn; or a metal compound including one or more metals of the metals. Alternatively, the n-type dopant may also be a material including cyclopentadiene, cycloheptatriene, a six-membered heterocyclic ring, or a condensed ring including these rings. At this time, the doping concentration may be from 0.01% by weight to 50% by weight, or from 1% by weight to 10% by weight.

As a specific example, the organic electroluminescent device includes first to third n-type organic material layers, in which the first n-type organic material layer may include the compound of Formula 1, and the second n-type organic material layer may be doped with an n-type dopant. At this time, the second n-type organic material layer and the third n-type organic material layer may include the compound of Formula 5 as a host material.

Cathode

As described above, in the present specification, a cathode material may be selected from materials having various work functions by including the above-described second organic material layer and first n-type organic material layer. It is preferred that the cathode material is usually a material having a small work function so as to facilitate electron injection. However, in the present specification, a material having a large work function may also be applied. Specifically, in the present specification, it is possible to use, as the cathode material, a material having a work function which is equal to or larger than the HOMO energy level of the above-described second organic material layer. For example, in the present specification, a material having a work function from 2 eV to 5 eV may be used as the cathode material. The cathode includes a metal such as magnesium, calcium, sodium, potassium, titanium, indium, yttrium, lithium, gadolinium, aluminum, silver, tin, and lead, or an alloy thereof; a multi-layer structured material such as LiF/Al or LiO₂/Al, and the like.

When Al is used as the cathode material, it is possible to provide a device capable of being efficiently operated by using Al either alone or together with LiF or Liq. In particular, when Ag is used as the cathode material, a device according to the related art is not operated well when Ag is used either alone or together with LiF or Liq, and thus as an organic material layer associated with the cathode, a layer composed of a metal such as an alkali metal or an alkaline earth metal, or an organic material layer doped with a metal needs to be used. However, in the exemplary embodiments described in the present specification, a material having a large work function, such as Ag, may be used as the cathode material without a metal layer or an organic material layer doped with a metal, as described above. In addition, in the exemplary embodiments described in the present specification, a transparent conductive oxide having a high work function such as IZO (work function from 4.8 eV to 5.2 eV) may also be used as the cathode material.

According to an exemplary embodiment of the present specification, the cathode may be provided so as to be in physical contact with the organic material layer. The organic material layer in contact with the cathode may be the above-described second organic material layer, and may be an additional organic material layer. Here, the organic material layer which is in contact with the cathode may be non-doped.

In the organic electroluminescent device in the related art, when a cathode of a material having a large work function, such as Al or Ag, is used, it is necessary to dope an inorganic material layer such as an LiF layer between an organic material layer and the cathode, or the organic material layer with a metal. In the related art, when the cathode is in contact with the organic material layer without using the inorganic material layer or the organic material layer doped with the metal as described above, only a material having a work function of 2 eV or more and less than 3.5 eV may be used as the cathode material. However, in the organic electroluminescent device according to the present specification, even when the cathode is in contact with the organic material layer, a cathode may be configured by using a material having a work function of 3.5 eV or more by the second organic material layer and the first n-type organic material layer.

According to an exemplary embodiment of the present specification, the cathode is provided so as to be in physical contact with the organic material layer, and the cathode is composed of a material having a work function of 3.5 eV or more.

According to an exemplary embodiment of the present specification, the cathode is provided so as to be in physical contact with the organic material layer, and the cathode is composed of a material having a work function of 4 eV or more.

According to an exemplary embodiment of the present specification, the cathode is provided so as to be in physical contact with the organic material layer, and the cathode is composed of a material having a work function of 4.5 eV or more.

The upper limit of the work function of the material constituting the cathode is not particularly limited, but it is possible to use a material having a work function of 5.5 eV or less from the viewpoint of selecting a material.

The cathode may be formed of a material which is the same as the anode. In this case, the cathode may be formed of the aforementioned materials exemplified as the material of the anode. Alternatively, the cathode or the anode may include a transparent material.

Hereinafter, specific examples of the above-described exemplary embodiments will be described. However, the following examples are illustrative only, and are not intended to limit the range of the exemplary embodiments.

The organic electroluminescent device according to an exemplary embodiment of the present specification may be a device including a light extraction structure.

In an exemplary embodiment of the present specification, the organic electroluminescent device further includes a substrate provided on a surface facing a surface of the anode or the cathode on which the organic material layer is provided, and a light extraction layer provided between the substrate and the anode or the cathode, or on a surface facing a surface of the substrate on which the anode or the cathode is provided.

In other words, the organic electroluminescent device further includes an internal light extraction layer between the substrate, which is provided on a surface facing a surface on which the organic material layer of the anode or the cathode is provided, and the anode or the cathode. In another exemplary embodiment, an external light extraction layer may be

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additionally provided on a surface opposite to a surface on which the anode or the cathode is provided on the substrate.

In the present specification, the internal light extraction layer or the external light extraction layer is not particularly limited as long as the layer has a structure which may induce light scattering so as to improve the light extraction efficiency of the device. In an exemplary embodiment, the light extraction layer may be formed by using a film having a structure in which scattering particles are dispersed in a binder, or unevenness.

In addition, the light extraction layer may be directly formed on a substrate by a method such as spin coating, bar coating, slit coating, and the like, or may be formed by a method of manufacturing the layer in a film form and attaching the layer.

In an exemplary embodiment of the present specification, the organic electroluminescent device is a flexible organic electroluminescent device. In this case, the substrate includes a flexible material. For example, it is possible to use glass having a flexible thin film form, plastic, or a substrate having a film form.

A material of the plastic substrate is not particularly limited, but generally, a film of PET, PEN, PI, and the like may be used in the form of a single layer or plural layers.

In an exemplary embodiment of the present specification, a display apparatus including the organic electroluminescent device is provided.

In an exemplary embodiment of the present specification, an illumination apparatus including the organic electroluminescent device is provided.

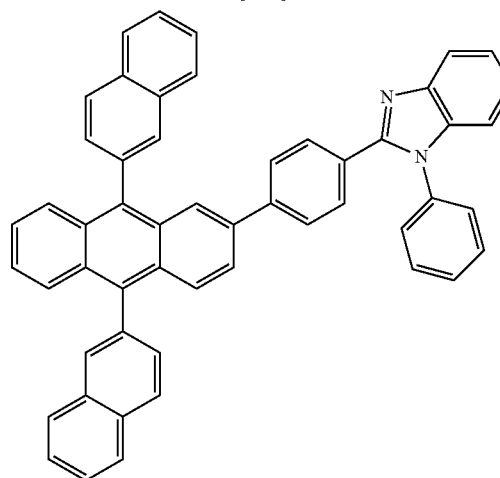
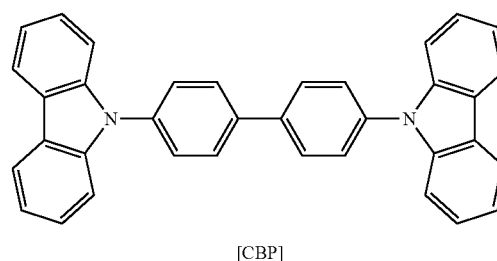
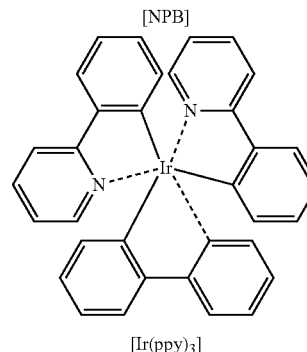
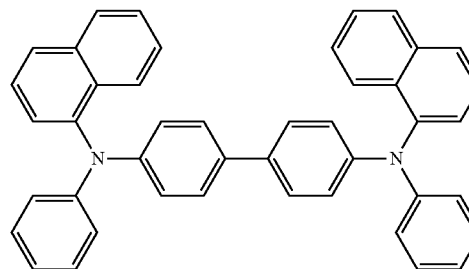
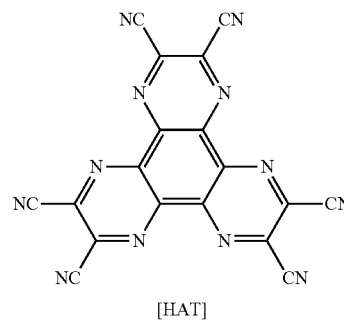
Example 1

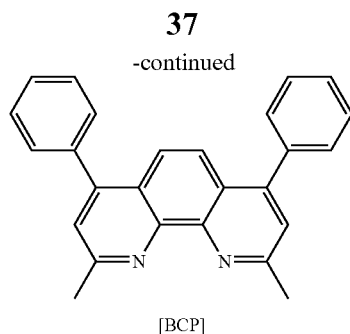
An anode having a thickness of 1,000 Å was formed on a substrate by a sputtering method using IZO, a HAT (the following formula) was formed thereon to have a thickness of 50 Å (LUMO energy level: 5.7 eV), and then a first organic material layer having a thickness of 500 Å was formed by thermally vacuum depositing an NPB and the HAT (the following formula) at a weight ratio of 30:70. Subsequently, a light emitting layer having a thickness of 300 Å was formed by doping a CBP of the following formula with an Ir(ppy)₃ of the following Formula in an amount of 10% by weight. A hole blocking layer having a thickness of 50 Å was formed thereon using a BCP of the following formula.

An organic material layer having a thickness of 100 Å was formed thereon using an electron transporting material of the following formula, and an electron transporting layer having a thickness of 50 Å was formed thereon by doping the electron transporting material of the following formula with Ca in an amount of 10% by weight.

The HAT (the following formula) was formed thereon to have a thickness of 300 Å (LUMO energy level: 5.7 eV), and then a second organic material layer having a thickness of 1,000 Å by thermally vacuum depositing the NPB (HOMO energy level: 5.4 eV) and the HAT (the following formula) at a weight ratio of 70:30. Finally, an organic electroluminescent device was manufactured by forming Ag (work function 4.7 eV) as the cathode to have a thickness of 2,000 Å.

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The deposition rate of the organic material in the process was maintained at a level from 0.5 Å/sec to 1 Å/sec, and the degree of vacuum during the deposition was maintained at a level from 2×10^{-7} torr to 2×10^{-8} torr.

Example 2

An organic electroluminescent device was manufactured in the same manner as in Example 1, except that the weight ratio of the NPB and the HAT in the second organic material layer was set to 80:20.

Example 3

An organic electroluminescent device was manufactured in the same manner as in Example 1, except that the weight ratio of the NPB and the HAT in the first organic material layer was set to 40:60.

Example 4

An organic electroluminescent device was manufactured in the same manner as in Example 3, except that the weight ratio of the NPB and the HAT in the second organic material layer was set to 80:20.

Example 5

An organic electroluminescent device was manufactured in the same manner as in Example 4, except that the weight ratio of the NPB and the HAT in the first organic material layer was set to 50:50.

Comparative Example 1

An organic electroluminescent device was manufactured in the same manner as in Example 1, except that the weight ratio of the NPB and the HAT in the first organic material layer was set to 70:30.

Example 6

An organic electroluminescent device was manufactured in the same manner as in Example 1, except that the weight ratio of the NPB and the HAT in the second organic material layer was set to 30:70.

Comparative Example 2

An organic electroluminescent device was manufactured in the same manner as in Comparative Example 1, except that the weight ratio of the NPB and the HAT in the second organic material layer was set to 30:70.

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The driving voltages and external quantum efficiencies of the devices in the Examples and the Comparative Examples are shown in the following Table 1.

TABLE 1

	First organic material layer (NPB:HAT)	Second organic material layer (NPB:HAT)	Driving voltage (V, @ 5 mA/cm ²)	External quantum efficiency (% , @ 5 mA/cm ²)
Example 1	30:70	70:30	6.5	12.0
Example 2	30:70	80:20	6.5	12.0
Example 3	40:60	70:30	6.5	12.0
Example 4	40:60	80:20	6.5	12.0
Example 5	50:50	80:20	6.5	11.5
Comparative Example 1	70:30	70:30	6.3	8.4
Example 6	30:70	30:70	6.5	10.0
Comparative Example 2	70:30	30:70	6.3	7.2

From the results of Table 1 showing characteristics of the Examples and the Comparative Examples, in the case of Examples 1 to 5 and 6 where the content of the HAT, which is a p-type dopant in the first organic material layer, was high, roughness of the organic material in the device was reduced and the amount of leakage current is reduced, and thus the stability of the device is improved, showing high efficiency. In the case of Examples 1 to 5 where the content of the p-type dopant in the second organic material layer is low, a higher efficiency is shown due to an effect of increasing scattering.

Table 2 and FIG. 5 show atomic force microscope (AFM) data when the weight ratio of the NPB and the HAT is varied. When the weight ratio of the HAT is low (less than 50% by weight), it can be seen that roughness of the organic film is increased, and a device with high efficiency may be implemented when the phenomenon is appropriately controlled and used in the first organic material layer (50% by weight or more) and the second organic material layer (less than 50% by weight).

TABLE 2

	Thickness (Å)	Scan size (mm ²)			
		4 (2 × 2)		25 (5 × 5)	
		Ra (nm)	Rmax (nm)	Ra (nm)	Rmax (nm)
HAT	1,000	2.14	27.4	2.32	32.7
NPB	1,000	0.98	10.4	0.99	13.1
NPB:HAT (30:70)	1,000	1.40	12.0	1.49	18.7
NPB:HAT (50:50)	1,000	2.41	38.2	2.30	35.2
NPB:HAT (50:50)	2,000	1.87	25.2	2.02	36.8
NPB:HAT (70:30)	1,000	11.6	116.5	8.52	98.3

The invention claimed is:

1. An organic electroluminescent device comprising:
 - an anode;
 - a cathode;
 - a light emitting layer provided between the anode and the cathode;
 - a first organic material layer being in physical contact with the anode and doped with a p-type dopant; and
 - a second organic material layer being in physical contact with the cathode and doped with a p-type dopant,

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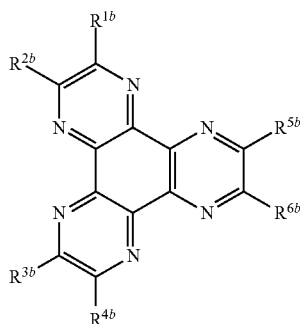
wherein a concentration of the p-type dopant in the first organic material layer is 50% by weight or more and less than 100% by weight.

2. The organic electroluminescent device of claim 1, wherein when the concentration of the p-type dopant in the first organic material layer is A % by weight and a concentration of the p-type dopant in the second organic material layer is B % by weight, $A \geq B$.

3. The organic electroluminescent device of claim 1, wherein when the concentration of the p-type dopant in the first organic material layer is A % by weight and a concentration of the p-type dopant in the second organic material layer is B % by weight, $A \geq 1.5 B$.

4. The organic electroluminescent device of claim 1, wherein when the concentration of the p-type dopant in the first organic material layer is A % by weight and a concentration of the p-type dopant in the second organic material layer is B % by weight, $A \geq 2 B$.

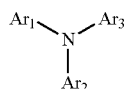
5. The organic electroluminescent device of claim 1, wherein the p-type dopant of the first organic material layer and the p-type dopant of the second organic material layer are a compound of the following Formula 1:



[Formula 1]

in Formula 1, R^{1b} to R^{6b} are each hydrogen, a halogen atom, nitrile (—CN), nitro (—NO₂), sulfonyl (—SO₂R), sulfoxide (—SOR), sulfonamide (—SO₂NR), sulfonate (—SO₃R), trifluoromethyl (—CF₃), ester (—COOR), amide (—CONHR or —CONRR'), a substituted or unsubstituted straight or branched C₁ to C₁₂ alkoxy, a substituted or unsubstituted straight or branched C₁ to C₁₂ alkyl, a substituted or unsubstituted straight or branched C₂ to C₁₂ alkenyl, a substituted or unsubstituted aromatic or non-aromatic heterocyclic ring, a substituted or unsubstituted aryl, a substituted or unsubstituted mono- or di-aryl amine, or a substituted or unsubstituted aralkyl amine, wherein R and R' are each a substituted or unsubstituted C₁ to C₆₀ alkyl, a substituted or unsubstituted aryl, or a substituted or unsubstituted 5- to 7-membered heterocyclic ring.

6. The organic electroluminescent device of claim 1, wherein in the first organic material layer and the second organic material layer, an organic material doped with the p-type dopant is a compound of the following Formula 2:



[Formula 2]

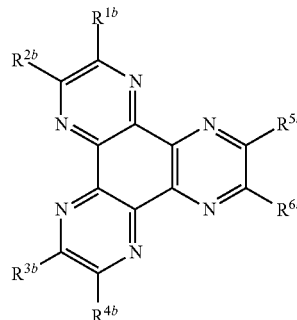
in Formula 2, Ar₁, Ar₂, and Ar₃ are each independently hydrogen or a hydrocarbon group.

7. The organic electroluminescent device of claim 6, wherein the p-type dopant in the second organic material

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layer is a compound of the following Formula 1, and a weight ratio of the compound of the following Formula 1 and the compound of the above Formula 2 is from 1:9 to 5:5;

[Formula 1]



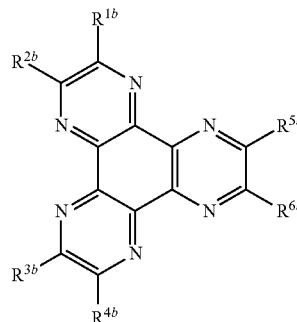
in Formula 1, R^{1b} to R^{6b} are each hydrogen, a halogen atom, nitrile (—CN), nitro (—NO₂), sulfonyl (—SO₂R), sulfoxide (—SOR), sulfonamide (—SO₂NR), sulfonate (—SO₃R), trifluoromethyl (—CF₃), ester (—COOR), amide (—CONHR or —CONRR'), a substituted or unsubstituted straight or branched C₁ to C₁₂ alkoxy, a substituted or unsubstituted straight or branched C₁ to C₁₂ alkyl, a substituted or unsubstituted straight or branched C₂ to C₁₂ alkenyl, a substituted or unsubstituted aromatic or non-aromatic heterocyclic ring, a substituted or unsubstituted aryl, a substituted or unsubstituted mono- or di-aryl amine, or a substituted or unsubstituted aralkyl amine, wherein R and R' are each a substituted or unsubstituted C₁ to C₆₀ alkyl, a substituted or unsubstituted aryl, or a substituted or unsubstituted 5- to 7-membered heterocyclic ring.

8. The organic electroluminescent device of claim 1, wherein an electron injection or transporting layer is provided between the second organic material layer and the light emitting layer.

9. The organic electroluminescent device of claim 8, wherein the electron injection or transporting layer is a first n-type organic material layer which is in contact with the second organic material layer.

10. The organic electroluminescent device of claim 9, wherein the first n-type organic material layer is formed of a compound of the following Formula 1:

[Formula 1]



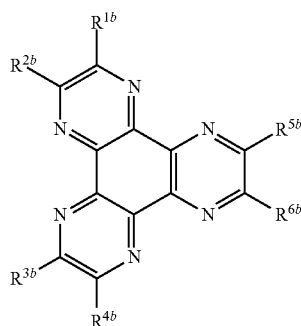
in Formula 1, R^{1b} to R^{6b} are each hydrogen, a halogen atom, nitrile (—CN), nitro (—NO₂), sulfonyl (—SO₂R), sulfoxide (—SOR), sulfonamide (—SO₂NR), sulfonate (—SO₃R), trifluoromethyl (—CF₃), ester (—COOR), amide (—CONHR or —CONRR'), a substituted or unsubstituted straight or branched C₁ to C₁₂ alkoxy, a substituted or unsubstituted straight or branched C₁ to

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C₁₂ alkyl, a substituted or unsubstituted straight or branched C₂ to C₁₂ alkenyl, a substituted or unsubstituted aromatic or non-aromatic heterocyclic ring, a substituted or unsubstituted aryl, a substituted or unsubstituted mono- or di-aryl amine, or a substituted or unsubstituted aralkyl amine, wherein R and R' are each a substituted or unsubstituted C₁ to C₆₀ alkyl, a substituted or unsubstituted aryl, or a substituted or unsubstituted 5- to 7-membered heterocyclic ring.

11. The organic electroluminescent device of claim 9, wherein the p-type dopant of the first organic material layer, the p-type dopant of the second organic material layer, and a material for the first n-type organic material layer are the same as each other.

12. The organic electroluminescent device of claim 11, wherein the p-type dopant of the first organic material layer, the p-type dopant of the second organic material layer, and a material for the first n-type organic material layer are a compound of the following Formula 1:



[Formula 1]

in Formula 1, R^{1b} to R^{6b} are each hydrogen, a halogen atom, nitrile (—CN), nitro (—NO₂), sulfonyl (—SO₂R), sulfoxide (—SOR), sulfonamide (—SO₂NR), sulfonate (—SO₃R), trifluoromethyl (—CF₃), ester (—COOR), amide (—CONHR or —CONRR'), a substituted or unsubstituted straight or branched C₁ to C₁₂ alkoxy, a substituted or unsubstituted straight or branched C₁ to

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C₁₂ alkyl, a substituted or unsubstituted straight or branched C₂ to C₁₂ alkenyl, a substituted or unsubstituted aromatic or non-aromatic heterocyclic ring, a substituted or unsubstituted aryl, a substituted or unsubstituted mono- or di-aryl amine, or a substituted or unsubstituted aralkyl amine, wherein R and R' are each a substituted or unsubstituted C₁ to C₆₀ alkyl, a substituted or unsubstituted aryl, or a substituted or unsubstituted 5- to 7-membered heterocyclic ring.

13. The organic electroluminescent device of claim 9, wherein a second n-type organic material layer is provided between the first n-type organic material layer and the light emitting layer.

14. The organic electroluminescent device of claim 13, wherein the second n-type organic material layer is n-type doped.

15. The organic electroluminescent device of claim 14, wherein a third n-type organic material layer is provided between the second n-type organic material layer and the light emitting layer.

16. The organic electroluminescent device of claim 1, wherein a fourth n-type organic material layer is provided between the first organic material layer and the anode.

17. The organic electroluminescent device of claim 1, further comprising:

- a substrate provided on a surface opposite to a surface of the cathode or the anode on which the organic material layer is provided; and
- a light extraction layer provided between the cathode or the anode and the substrate, or on a surface opposite to a surface of the substrate on which the anode or the cathode is provided.

18. The organic electroluminescent device of claim 1, wherein the organic electroluminescent device is a flexible organic electroluminescent device.

19. A display comprising the organic electroluminescent device of claim 1.

20. An illumination apparatus comprising the organic electroluminescent device of claim 1.

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